

# Model Based Climate Predictions for Utah



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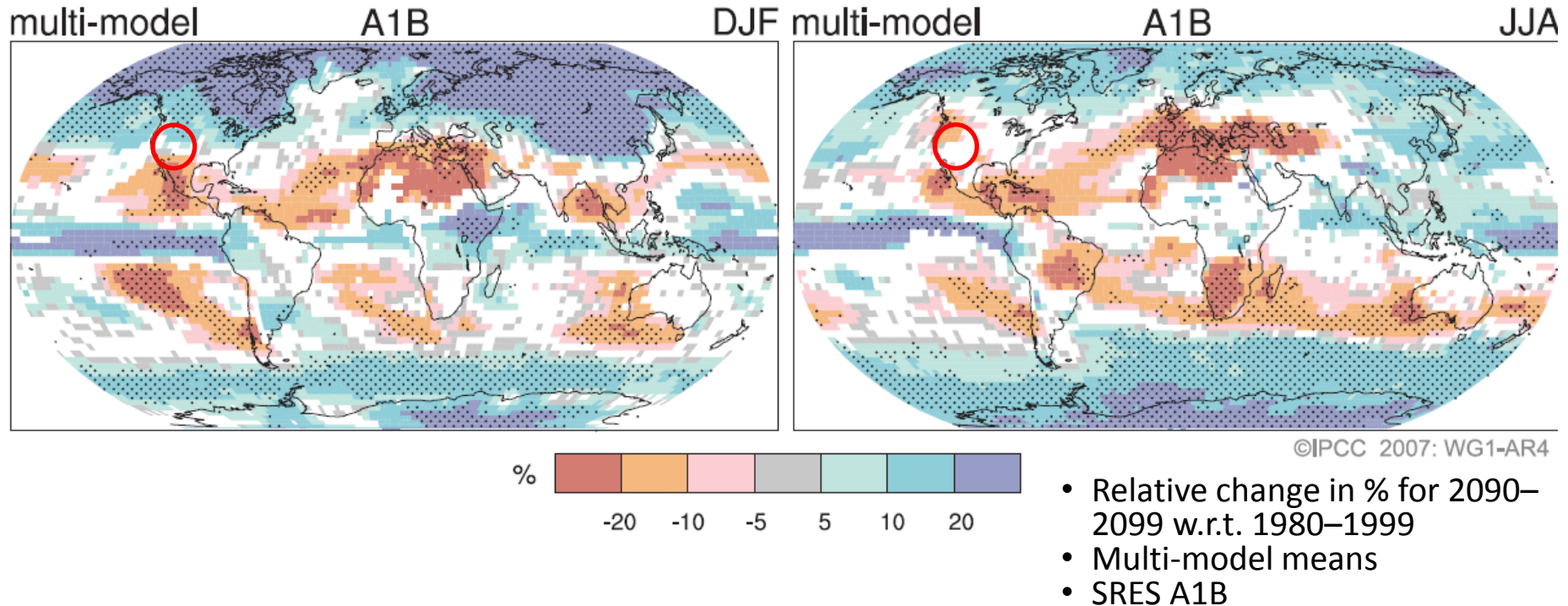
# Main Findings

- Precipitation over Northern Utah will increase by ~10% in winter and decrease by ~10% in summer
- Precipitation over Southern Utah will experience smaller precipitation change of the same sign
- Uniform temperature rise by ~3°F in winter and ~4°F in summer
- Warming and drying during summer work in the same direction and will lead to increased demand for water
- Warming and moistening during winter oppose each other with uncertain impacts on snow pack and water supply



# The “Resolution Problem”

## IPCC-AR4: Projected Precipitation Change



Current GCMs are too coarsely resolved  
for making meaningful regional predictions!

# Solutions

## A. High-resolution GCM

- expensive
- x2 resolution, x16 resources
- clean

## B. Downscaling

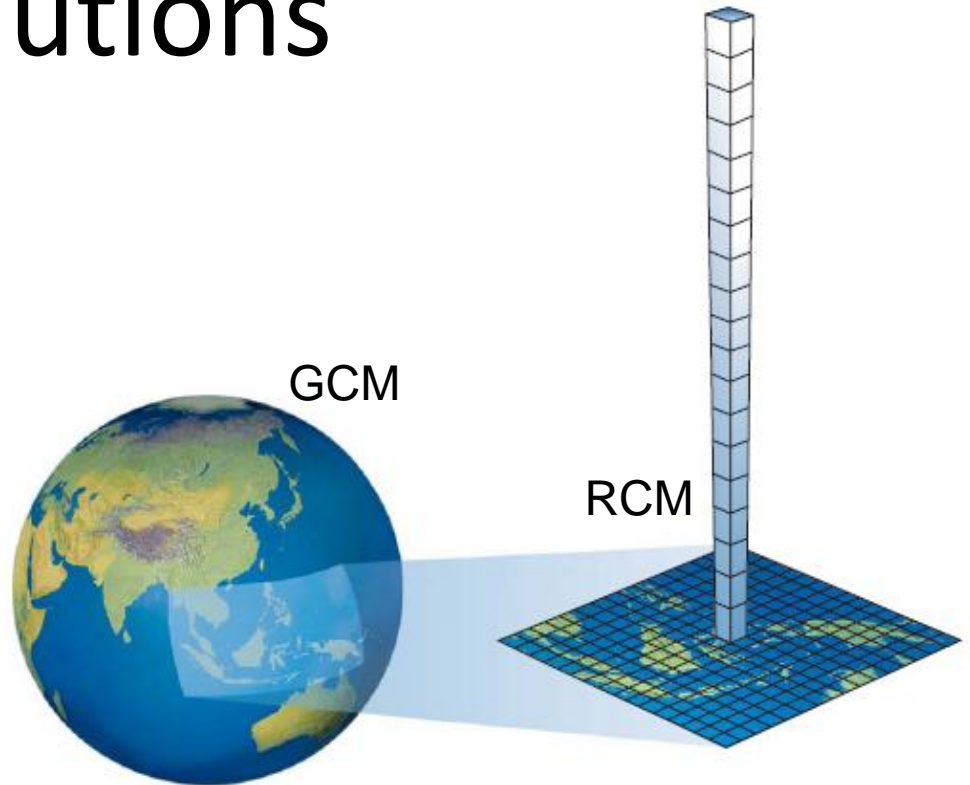


### 1. Dynamical

- nest high resolution RCM into coarse resolution GCM
- expensive
- model uncertainties
- North American Regional Climate Change Assessment Project (NARCCAP)

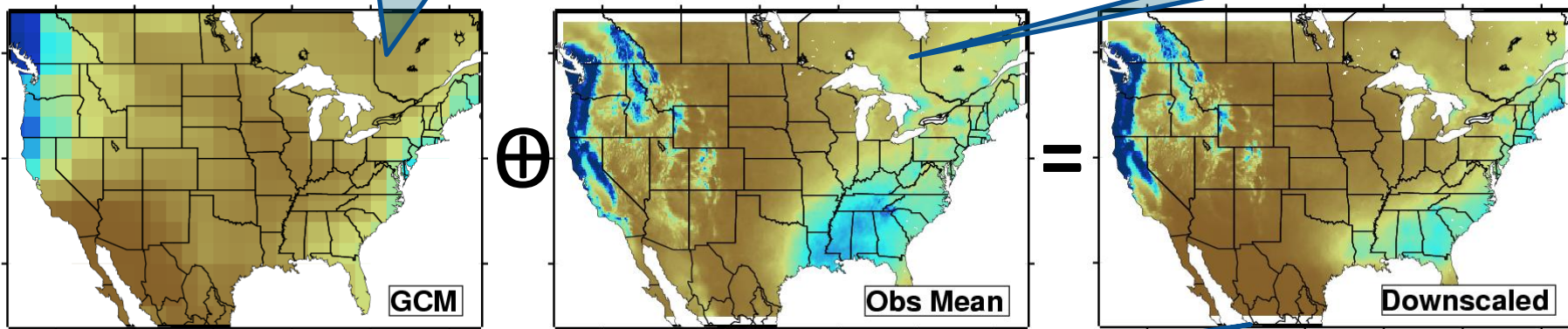
### 2. Statistical

- statistical correction of model prediction based on current climate
- cheap
- reminder of this talk



# Statistical Downscaling

1. For present climate, establish a statistical relationship betw. coarse model data (= predictor) and fine-scale observations (= predictand)



2. Correct model deficiencies by applying the relationship, which was established for today's climate, to model data for future climate (= downscaled)

## Critical assumptions

- statistical stationarity: relationship between coarse- and fine-scale data do not change
- model biases do not change

# High-Resolution US Downscaling

- **Monthly mean precipitation and temperature, 1950-2099**
- Lawrence Livermore National Laboratory (LLNL), Bureau of Reclamation, and Santa Clara University (SCU)
- Methodology: Wood et al. 2004, Maurer 2007
- US only: 1/8 degree (ca. 12x12 km)
- 16 GCMs (IPCC-AR4), 3 scenarios (A2, A1B, B1)
- [gdo-dcp.ucllnl.org/downscaled\\_cmip3\\_projections/](http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/)



# Precipitation Change

IPCC Scenario A1B (A2)

**20 year averages, centered at**  
**1990** (reference),  
**2050** (A1B),  
**2090** (A2)

<b>Winter</b>	<b>Summer</b>
Nov-Apr	May-Oct

**Multi-model means**  
16 models

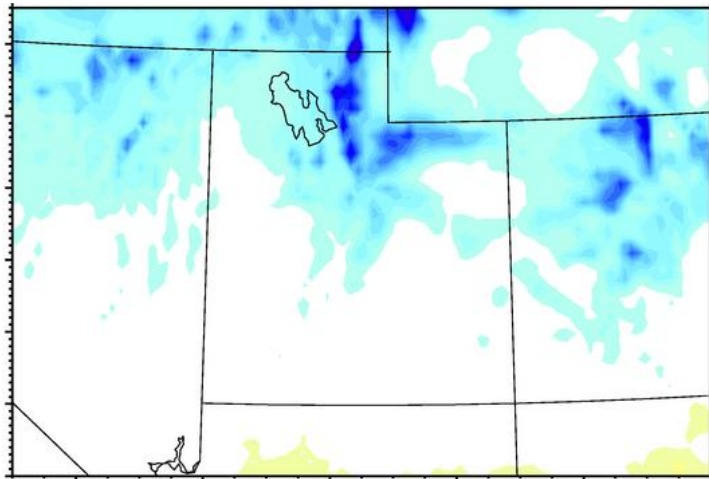
# Precipitation Change

A1B, 2050 minus 1990

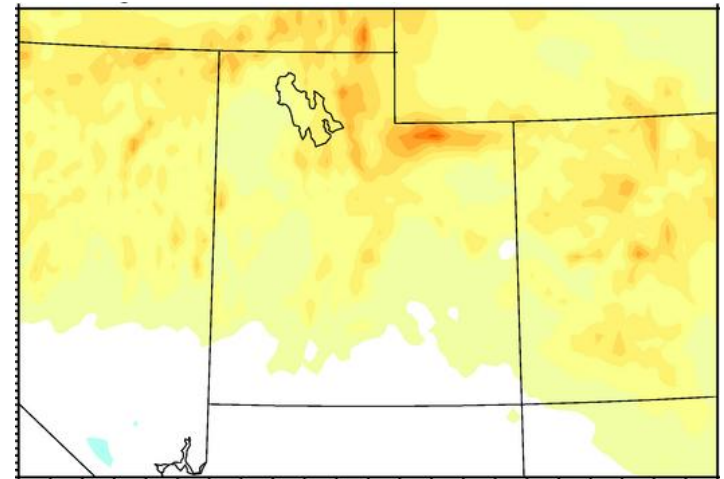
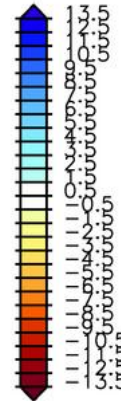
Nov-Apr

May-Oct

Absolute



mm/month





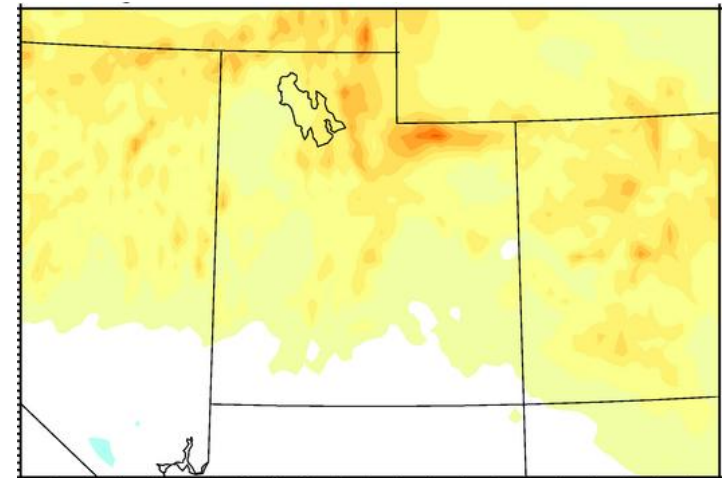
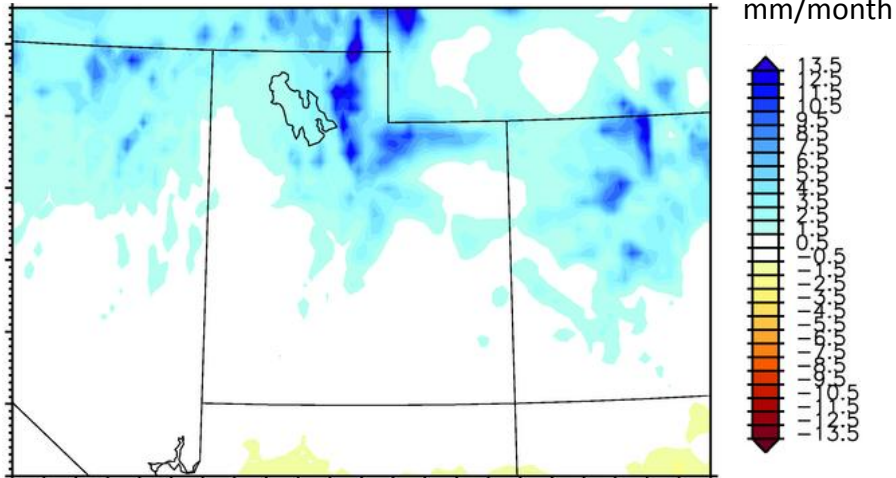
# Precipitation Change

A1B, 2050 minus 1990

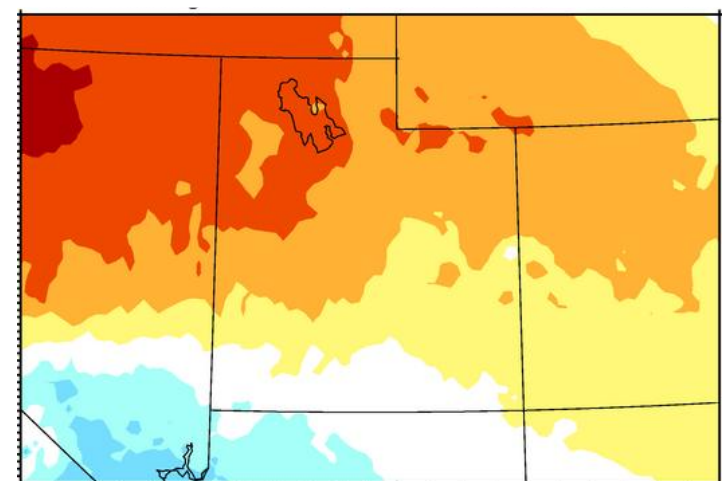
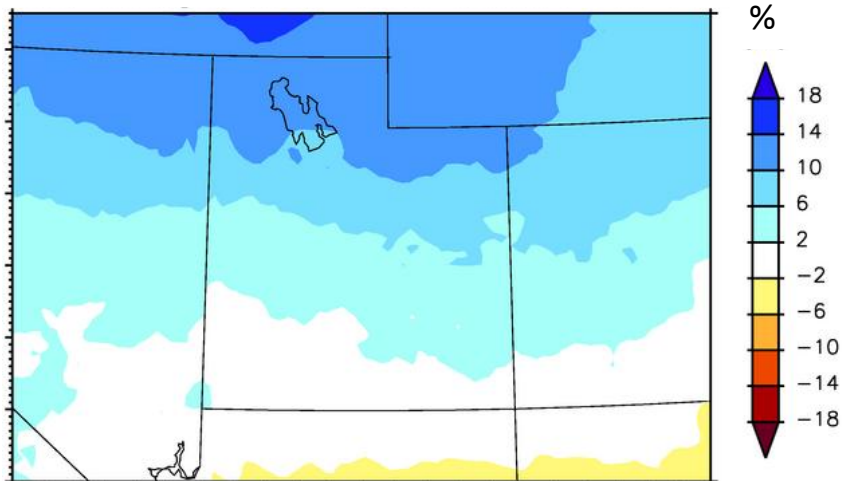
Nov-Apr

May-Oct

Absolute



Relative



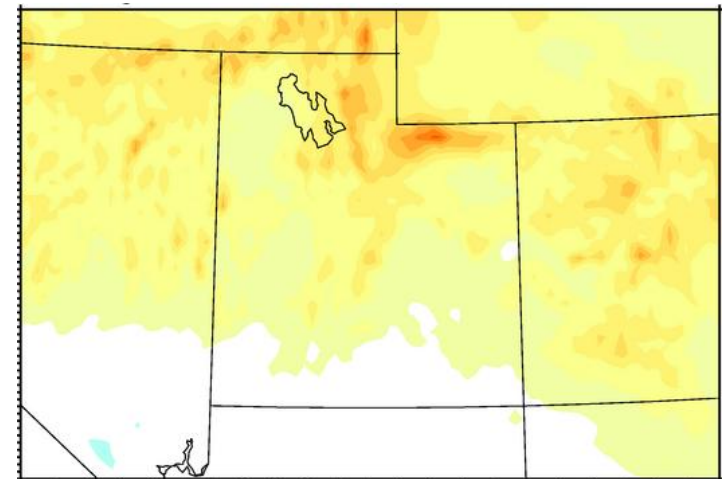
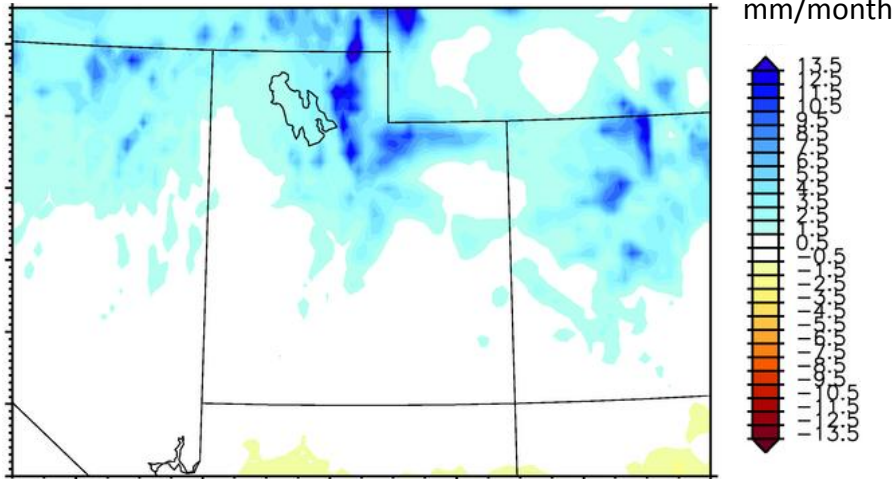
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A1B, 2050 minus 1990

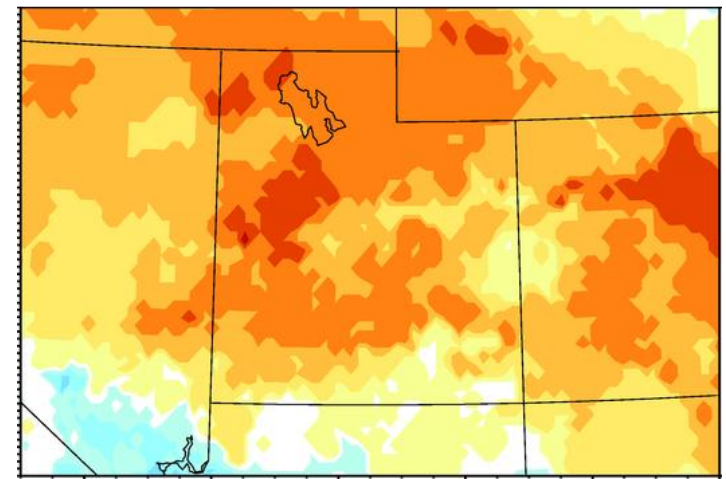
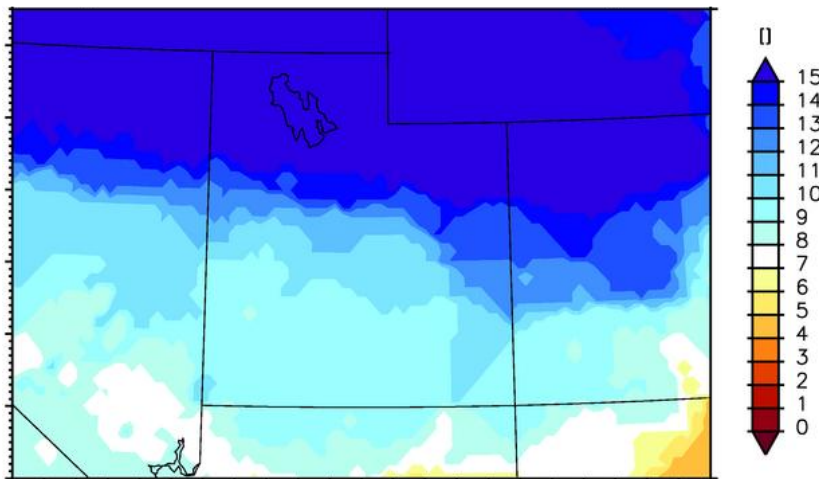
Nov-Apr

May-Oct

Absolute



# of models with positive change



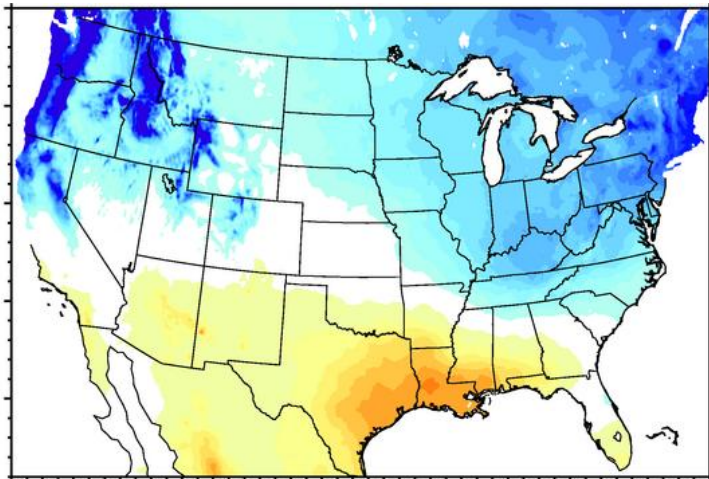
# Precipitation Change

A1B, 2050 minus 1990

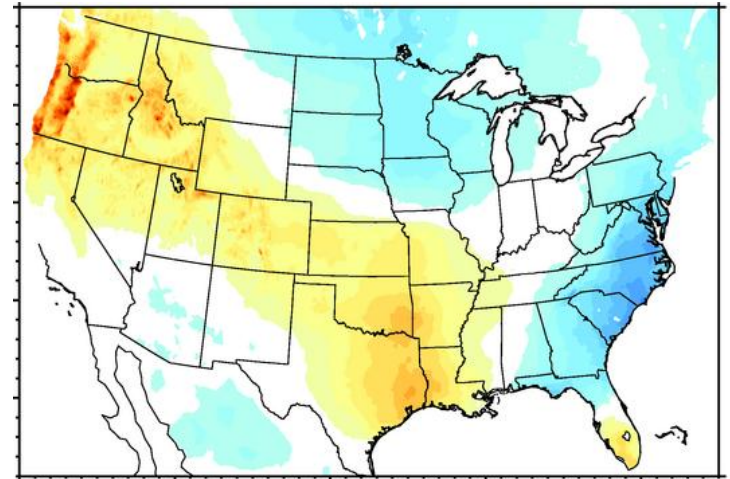
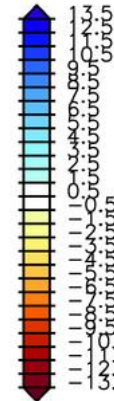
Nov-Apr

May-Oct

Absolute



mm/month





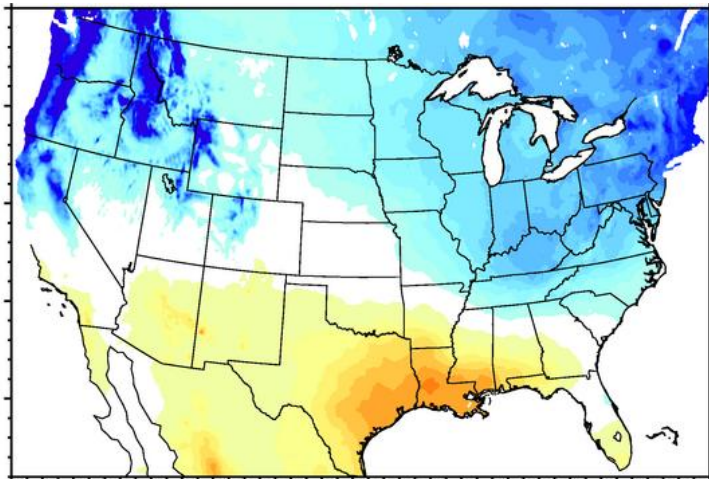
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A1B, 2050 minus 1990

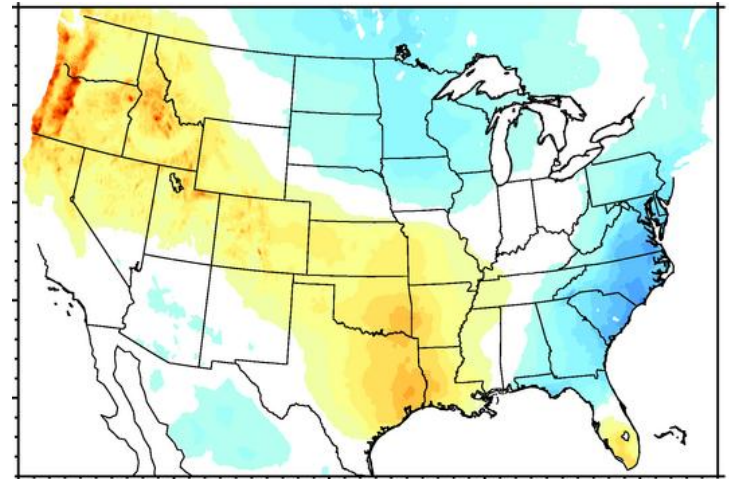
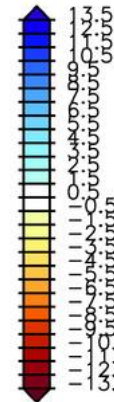
Nov-Apr

May-Oct

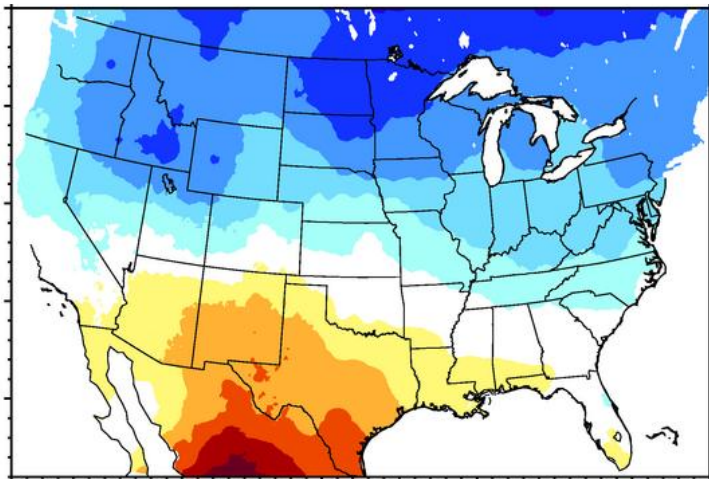
Absolute



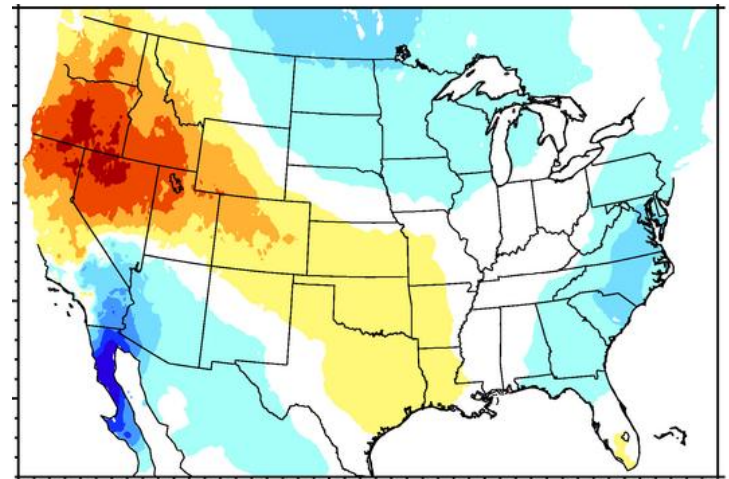
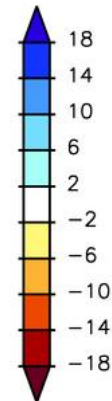
mm/month



Relative



%





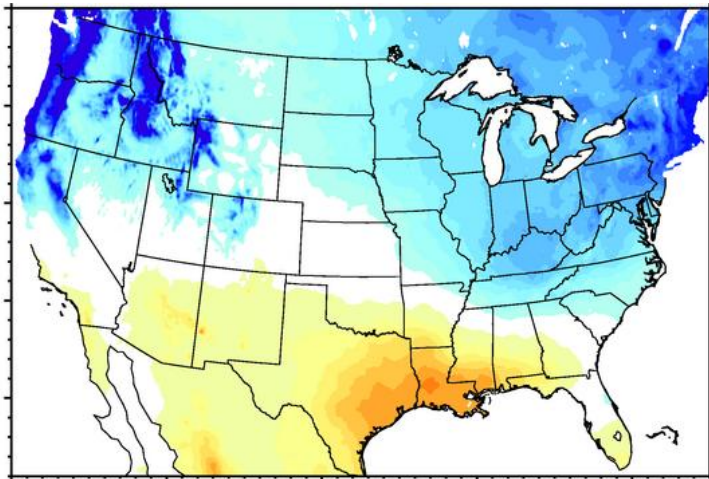
# Precipitation Change

A1B, 2050 minus 1990

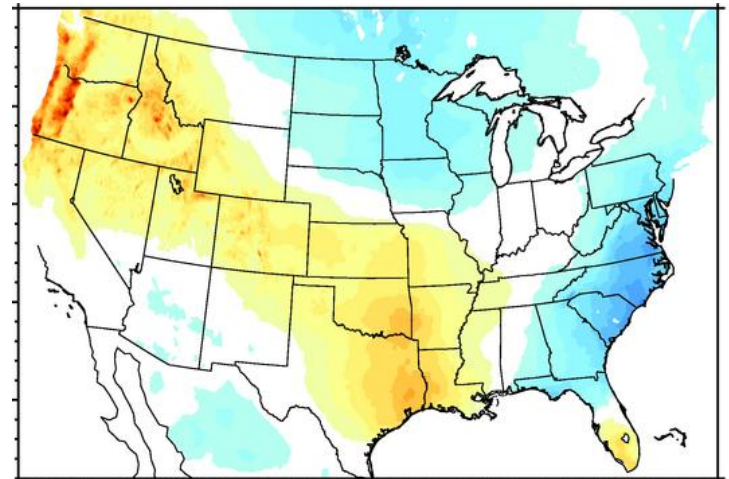
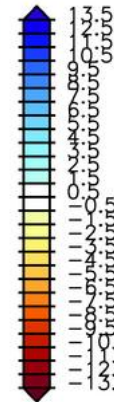
Nov-Apr

May-Oct

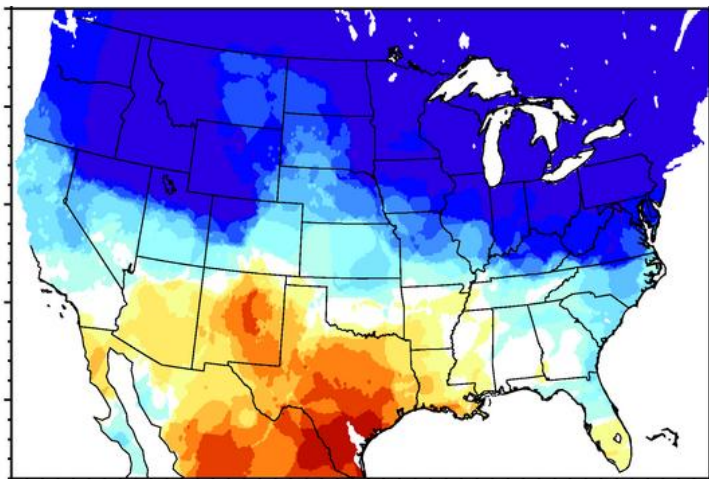
Absolute



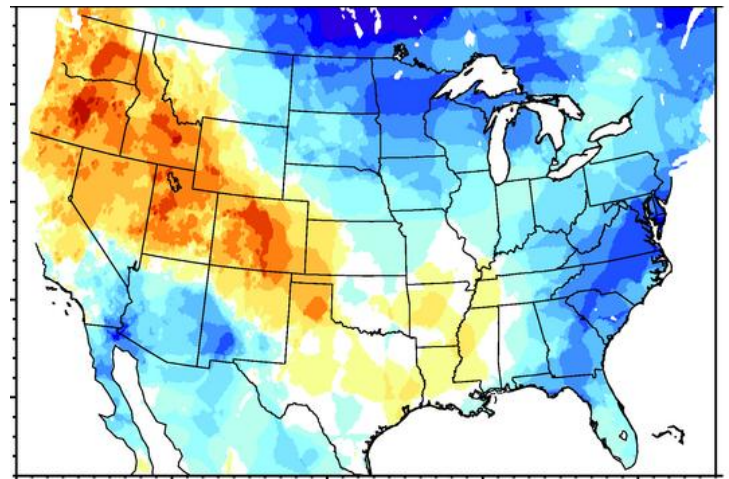
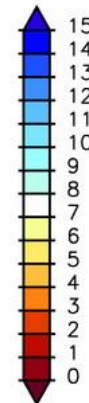
mm/month



Models with  
positive change



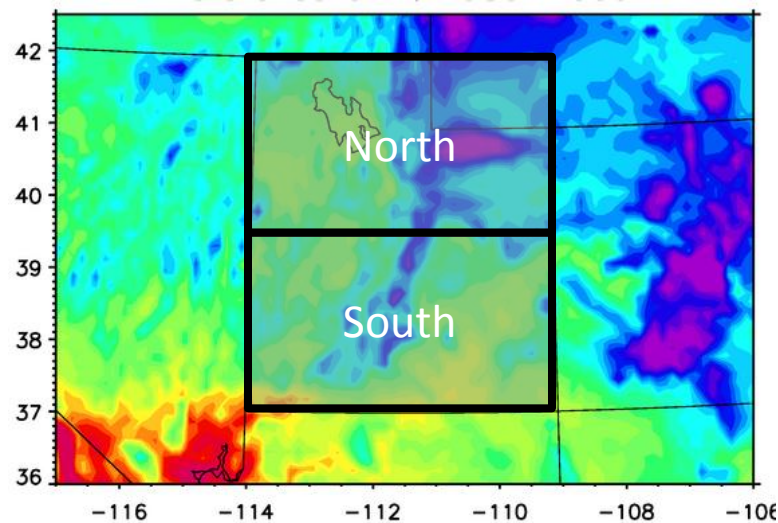
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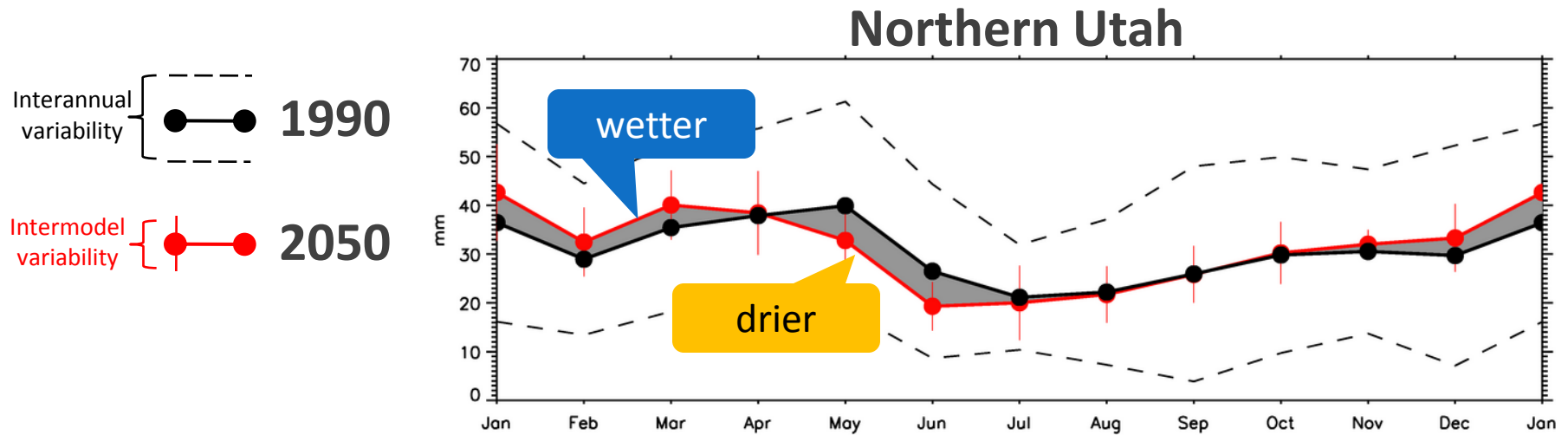
# Seasonal Cycle Changes

## Northern vs. Southern Utah

	Longitude	Latitude
Northern Utah	114°W-109°W	39.5°W-42°N
Southern Utah	114°W-109°W	37°W-39.5°N



# Precipitation Change: A1B

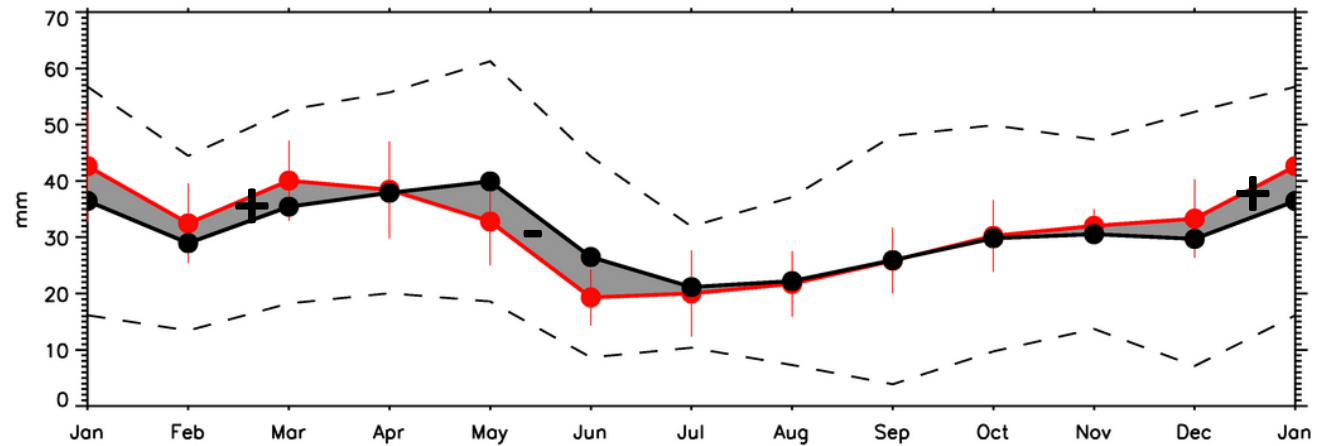


# Precipitation Change: A1B

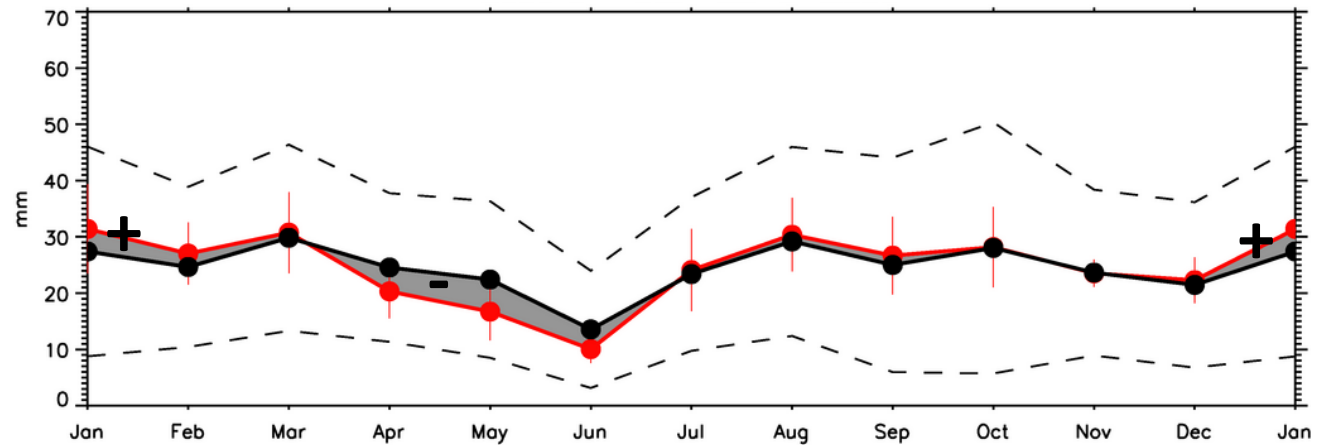
Interannual variability { ● — ● } **1990**

Intermodel variability { ● — ● } **2050**

## Northern Utah



## Southern Utah



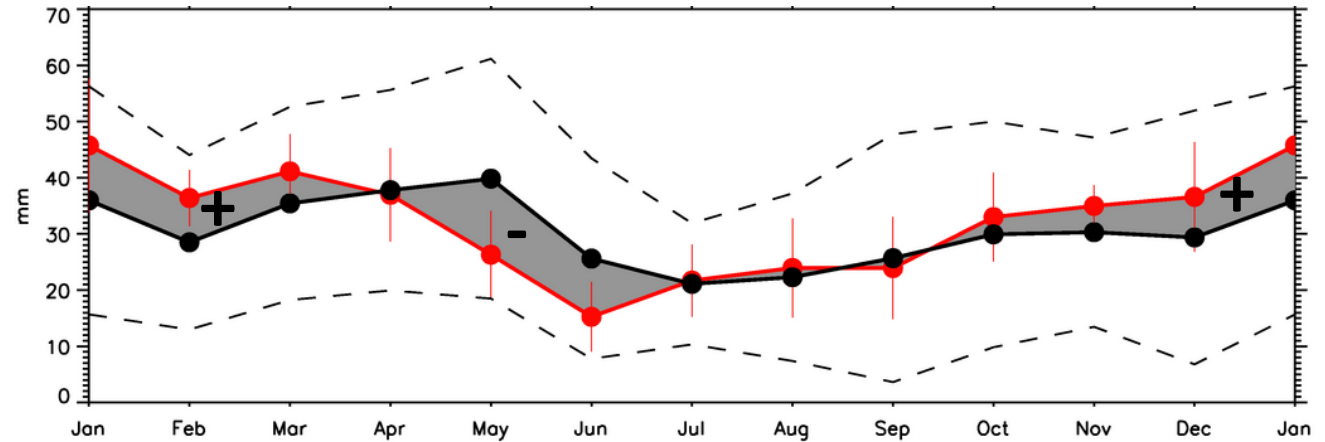


# Precipitation Change: A2

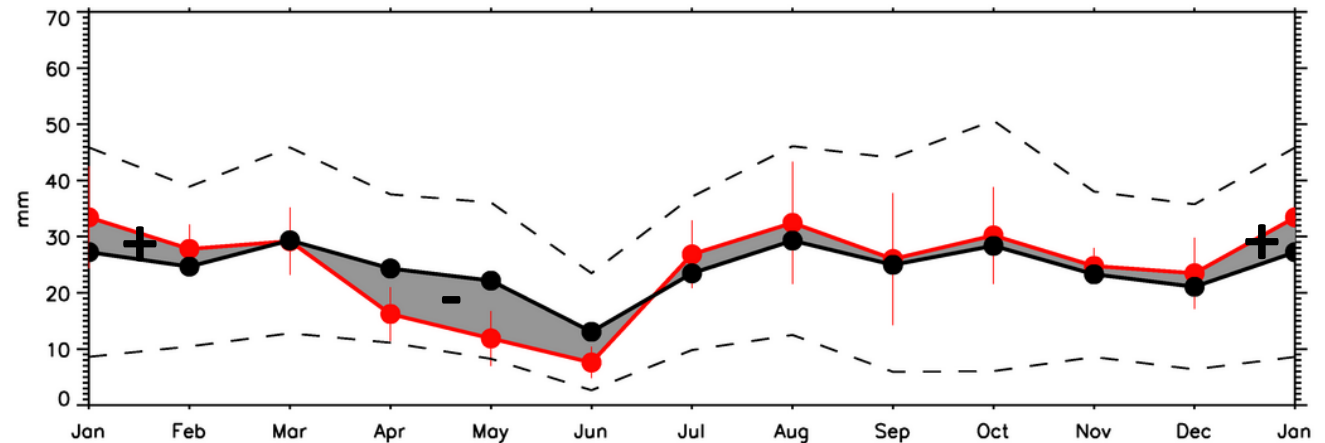
Interannual variability { ● — ● } **1990**

Intermodel variability { ● — ● } **2090**

## Northern Utah



## Southern Utah



# Temperature Change

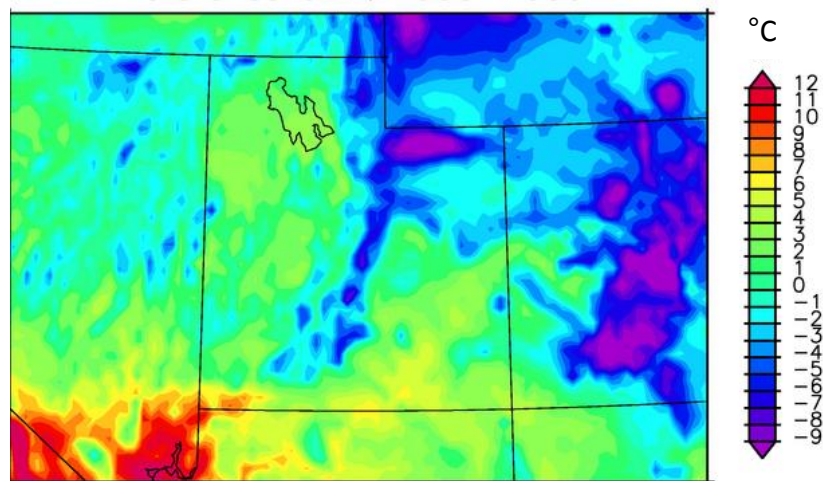
IPCC Scenario A1B (A2)

# Temperature Change

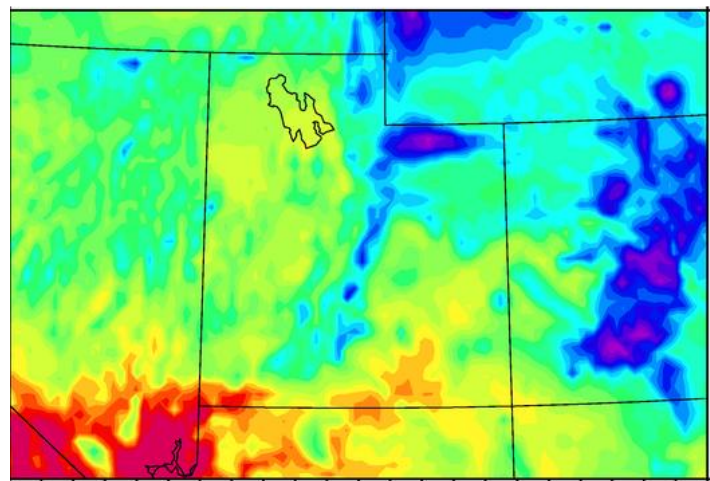
A1B, 1990 vs. 2050

Nov-Apr

1980-1999



2040-2059



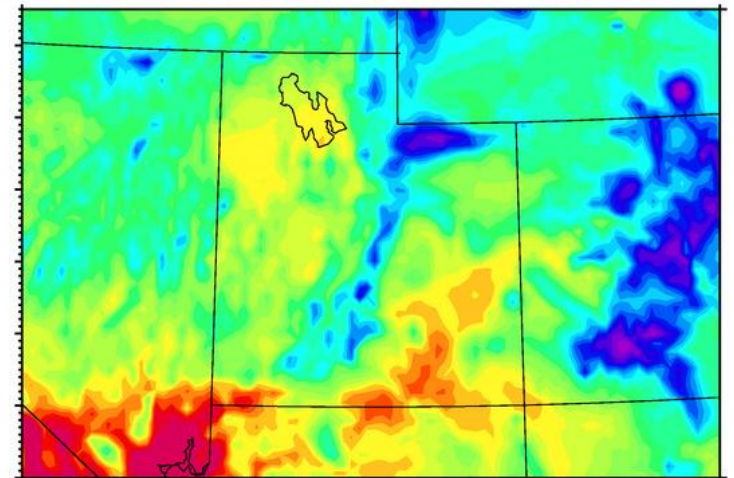
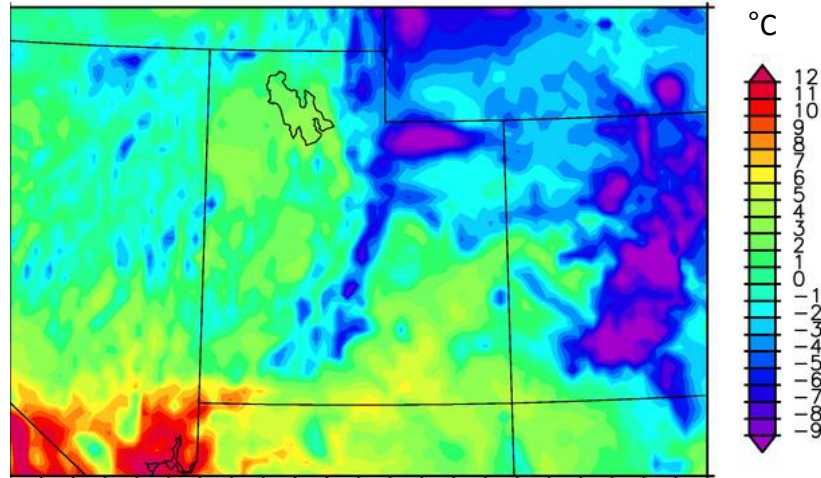
# Temperature Change

A1B, 1990 vs. 2050

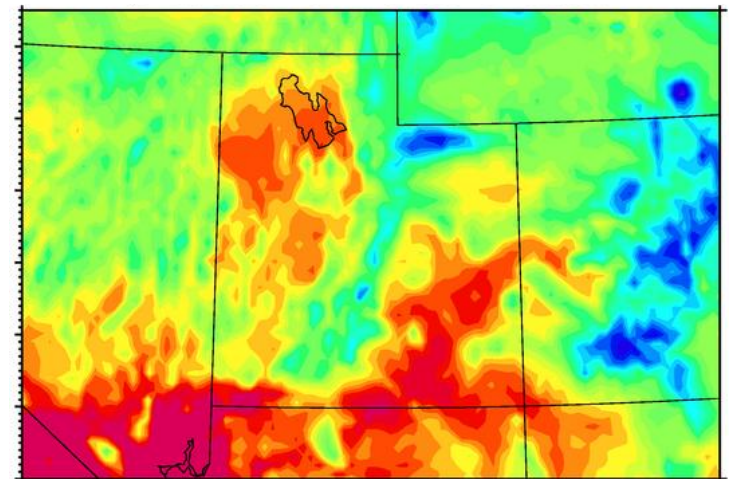
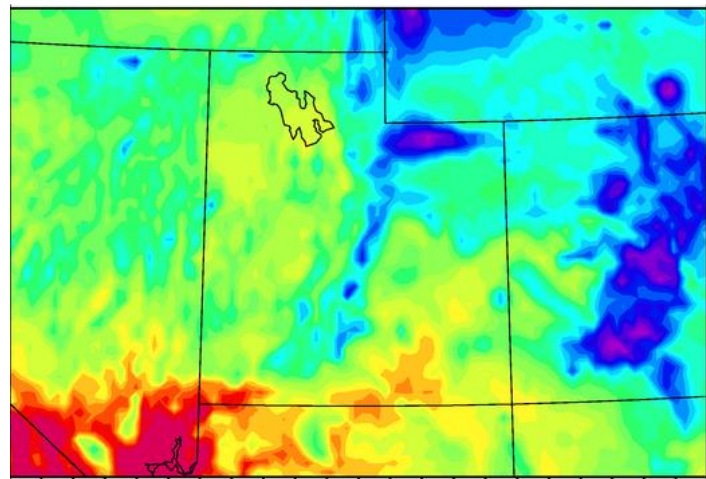
Nov-Apr

May-Oct

1980-1999



2040-2059





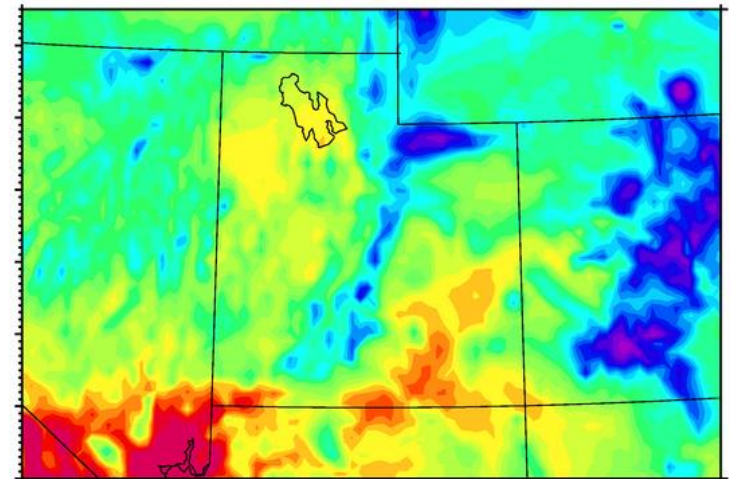
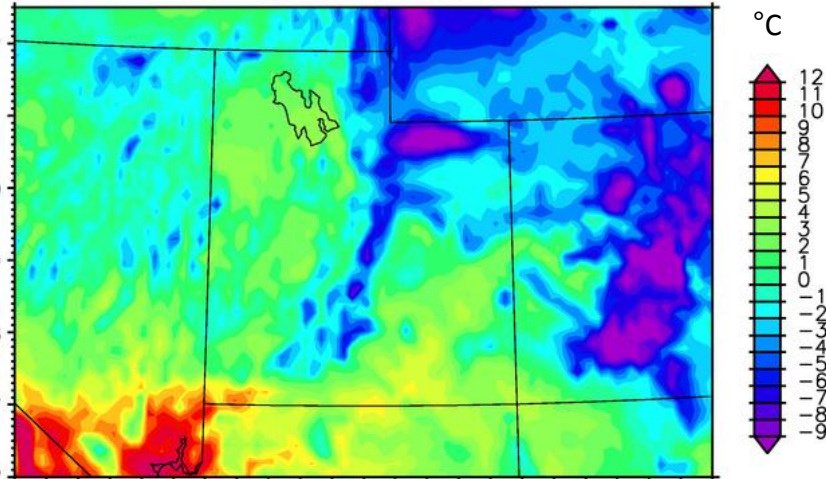
# Temperature Change

A1B, 1990 vs. 2050

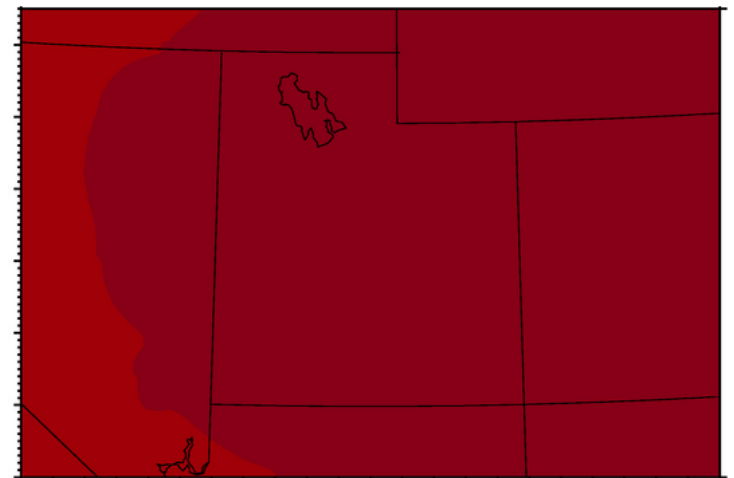
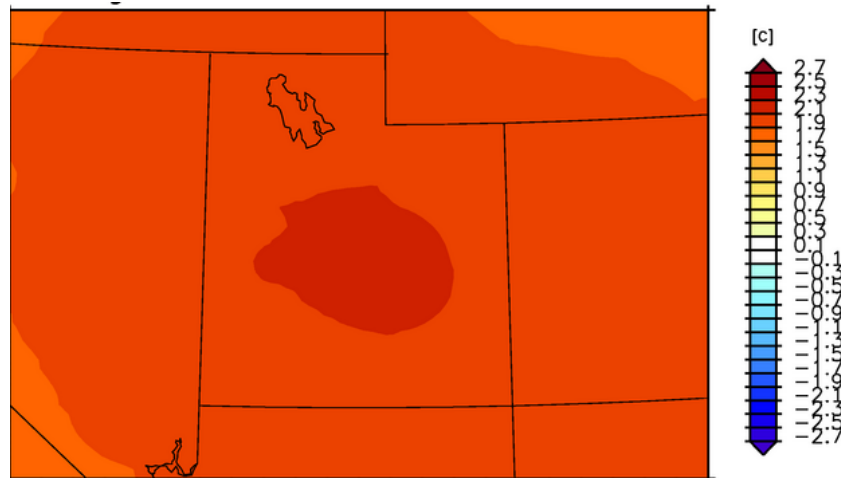
Nov-Apr

May-Oct

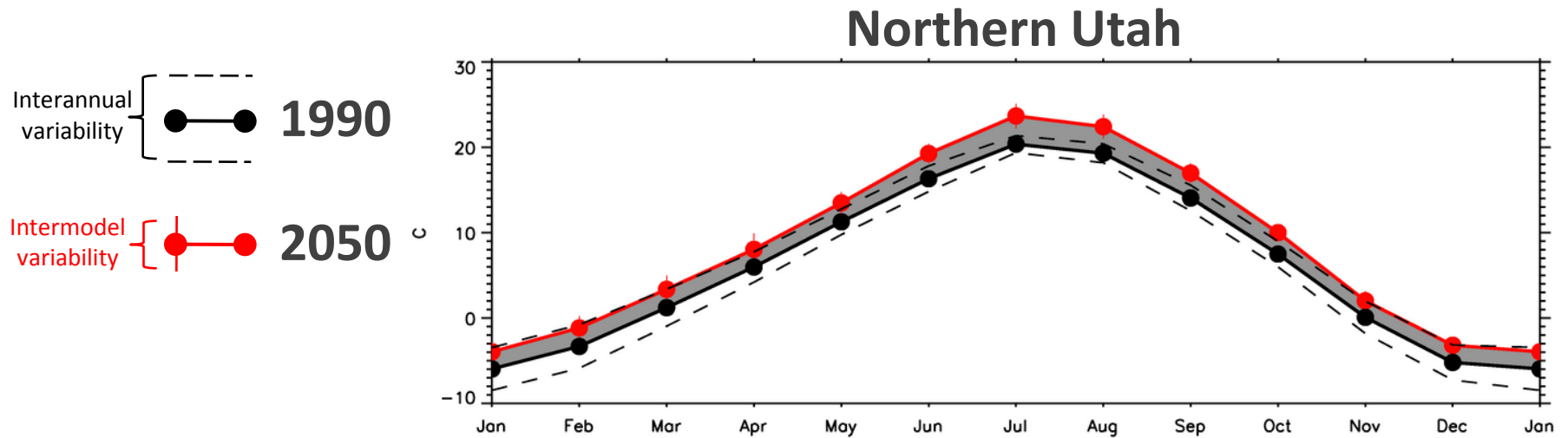
1980-1999



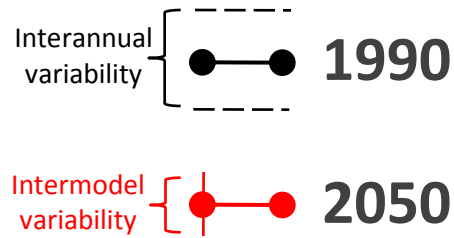
Change



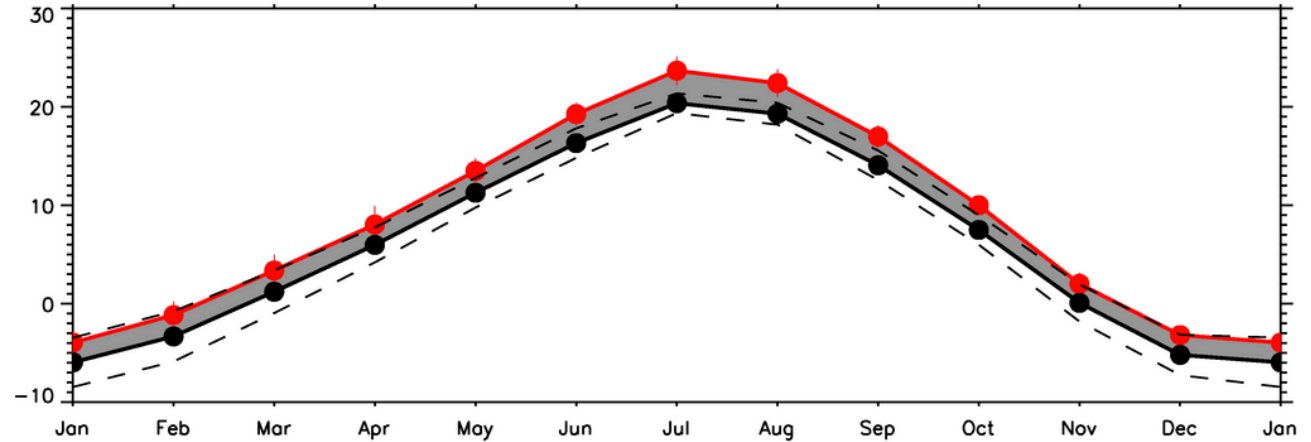
# Temperature Change: A1B



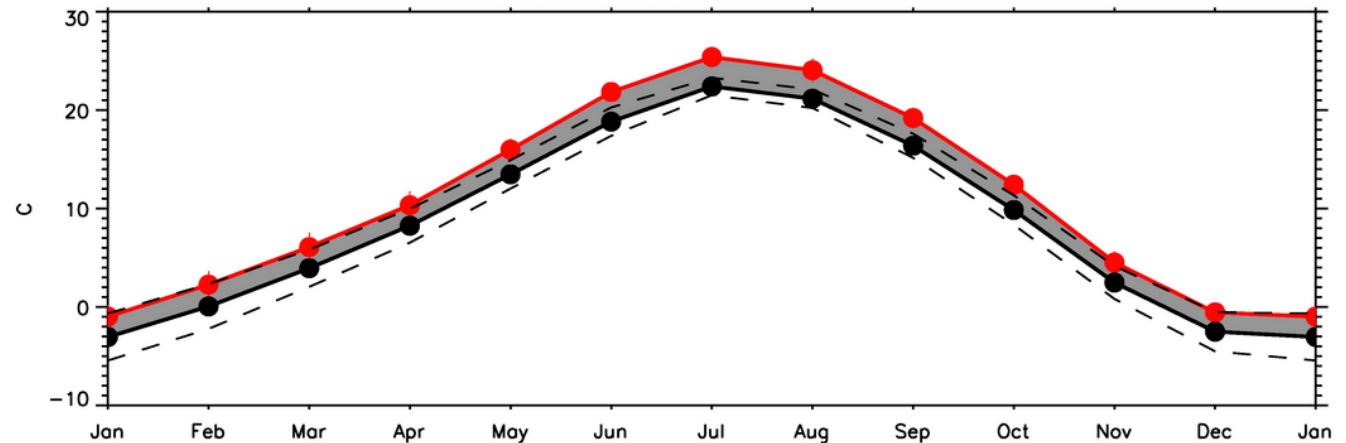
# Temperature Change: A1B



## Northern Utah



## Southern Utah

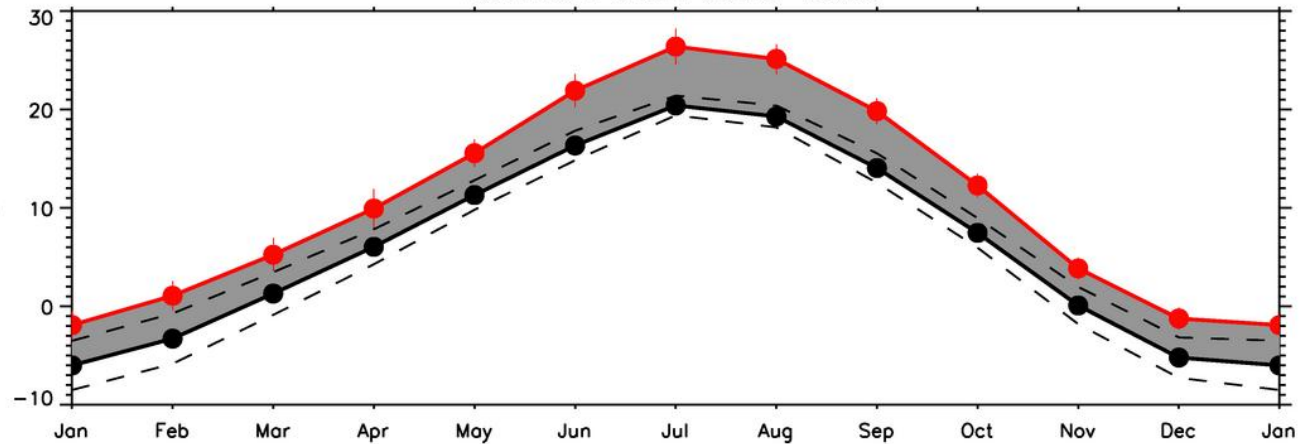


# Temperature Change: A2

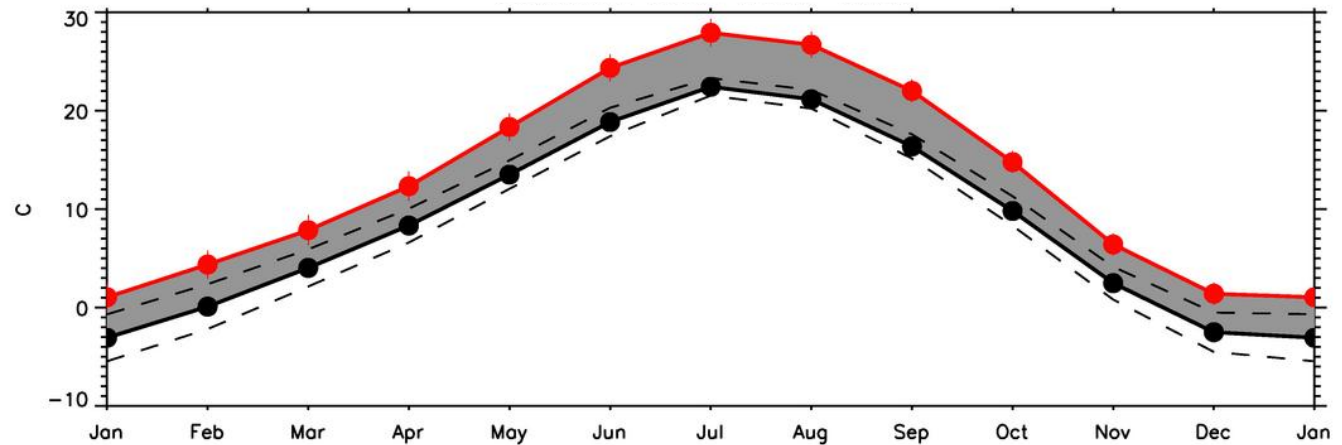
Interannual variability { ● — ● } **1990**

Intermodel variability { ● — ● } **2090**

## Northern Utah



## Southern Utah





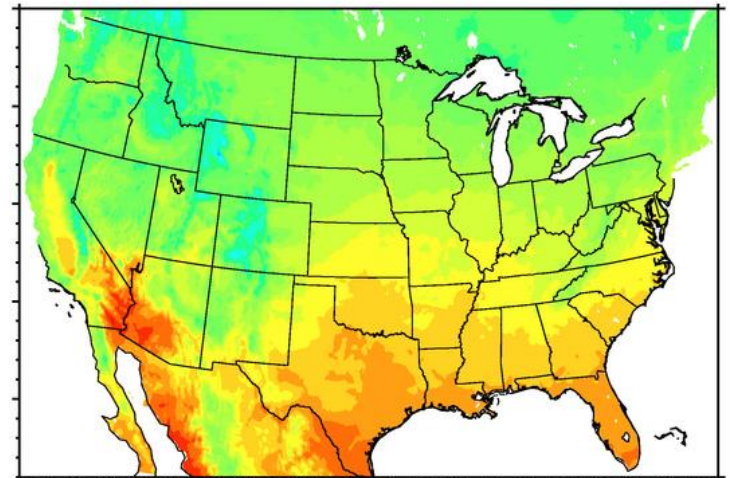
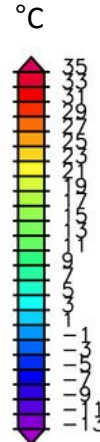
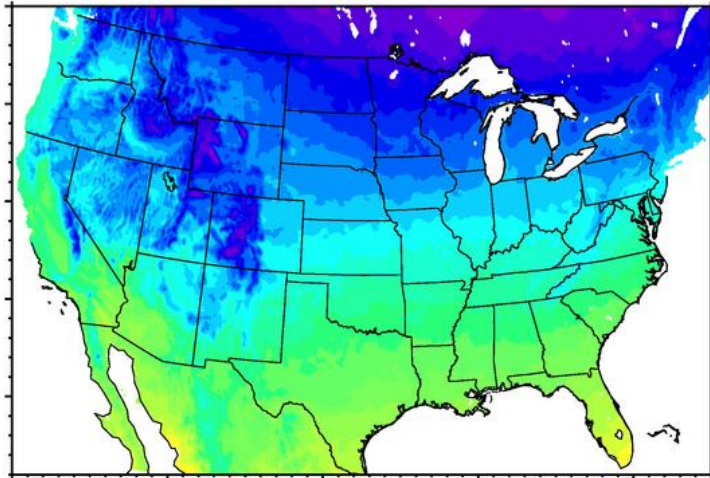
# Temperature Change

A1B, 1990 vs. 2050

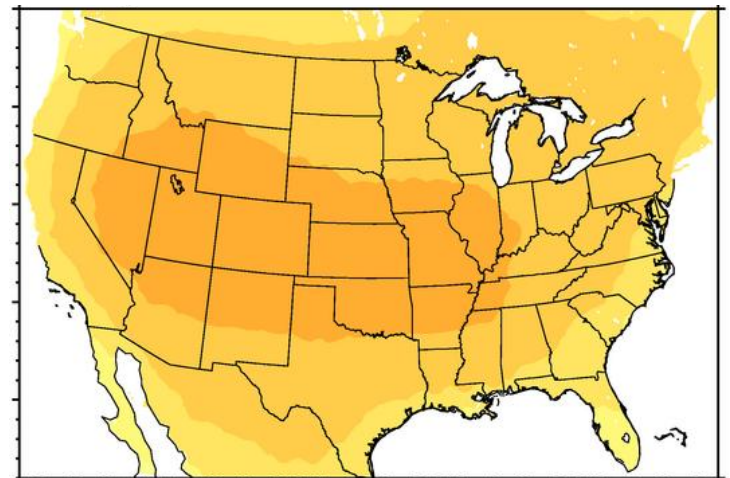
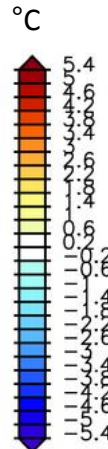
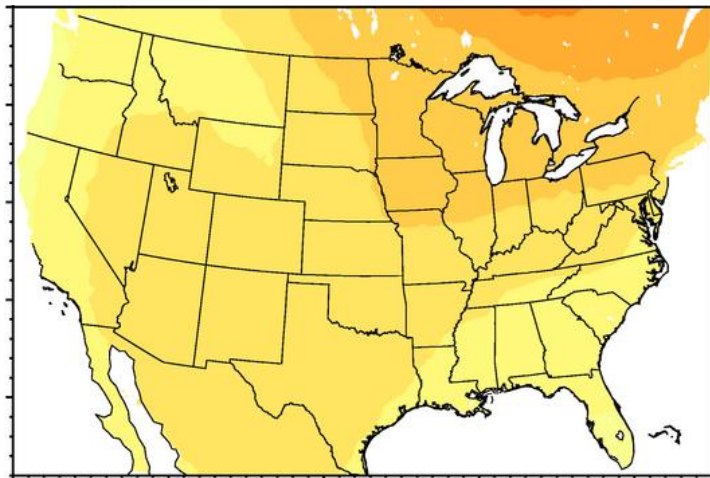
Nov-Apr

May-Oct

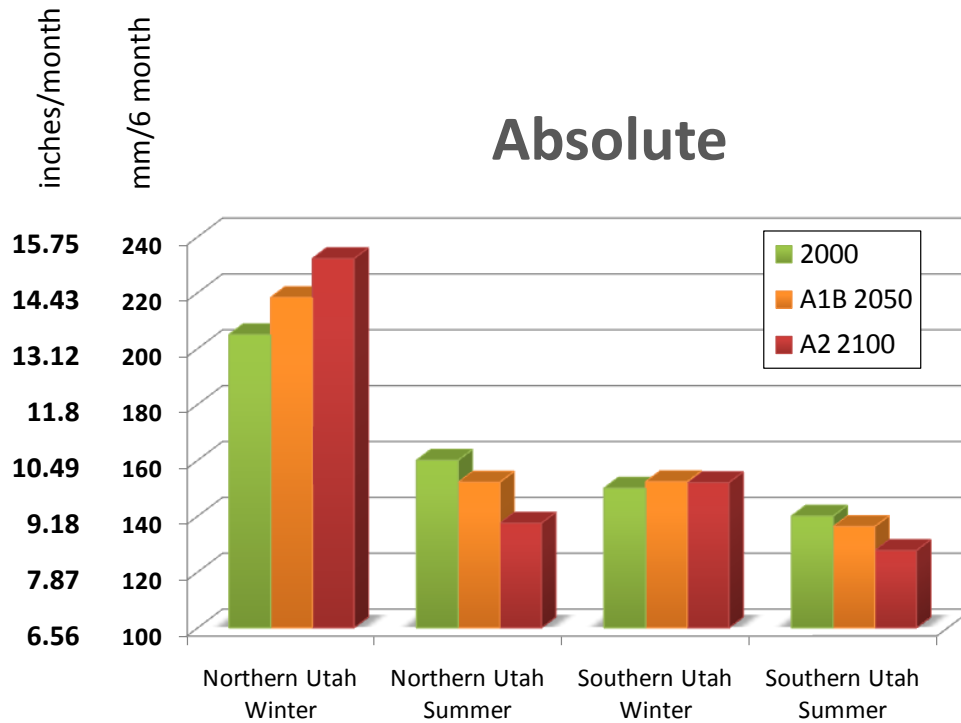
1980-1999



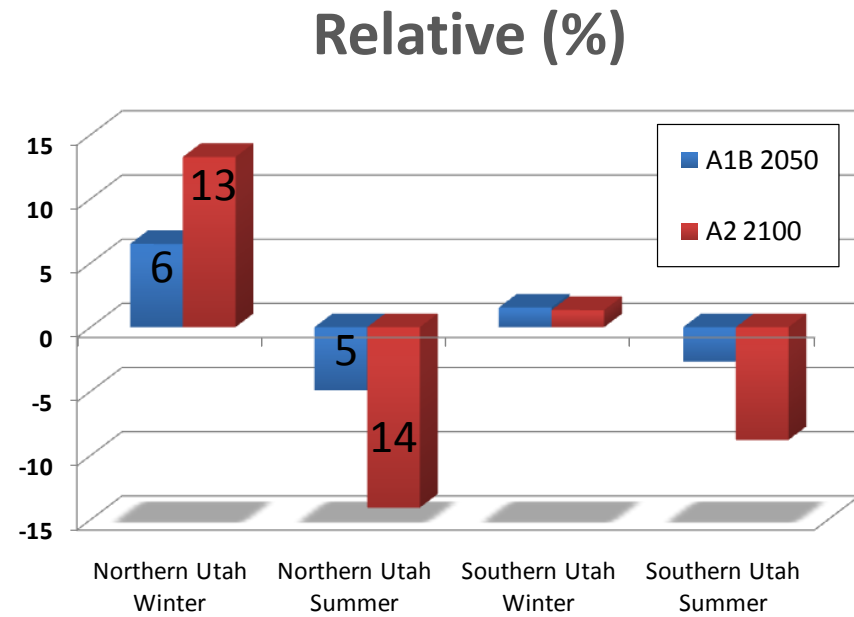
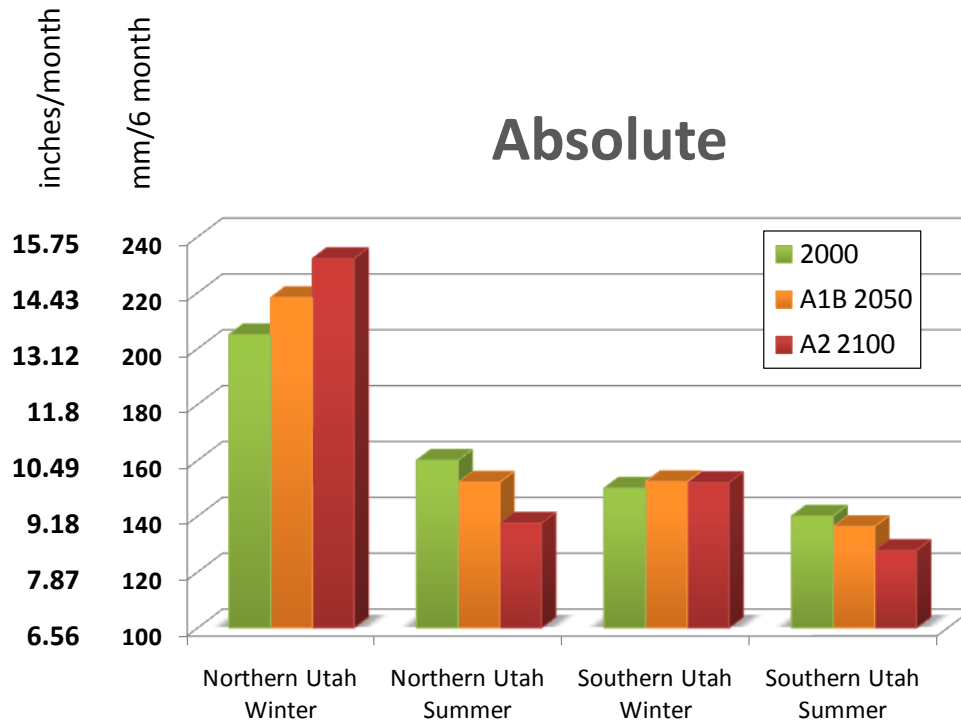
Change



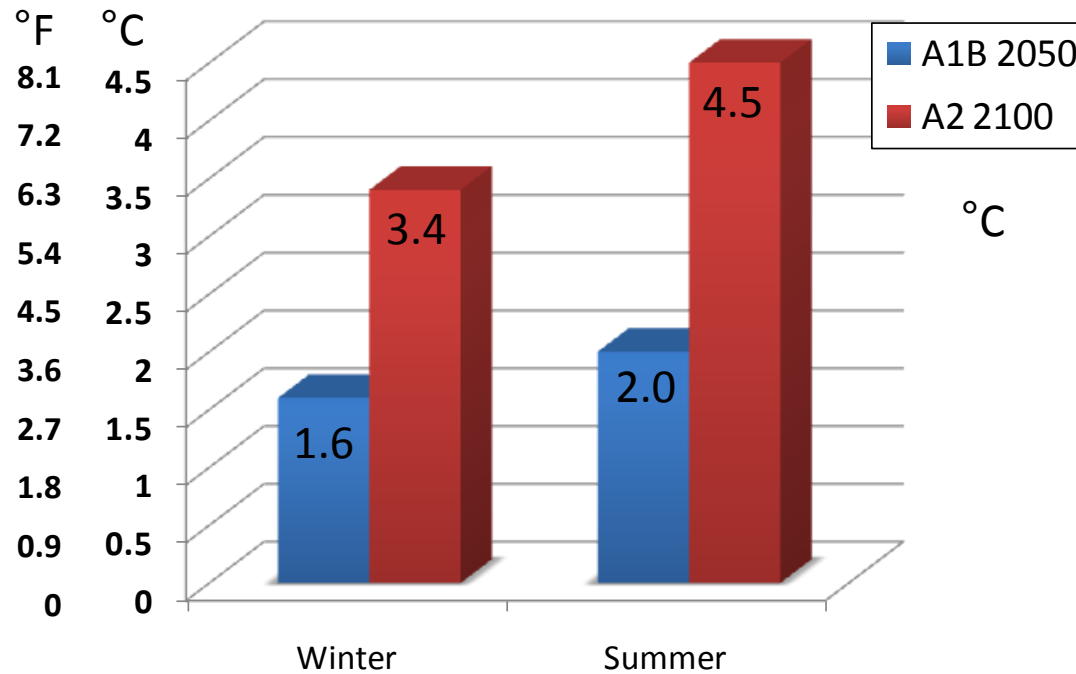
# Precipitation Change



# Precipitation Change



# Temperature Change





# Why Should We Believe This?

- Change is consistent with theoretical expectations
  1. General global warming
    - amplified over higher latitudes, continent interiors, mountains
  2. Intensified hydrological cycle
    - “wetter gets wetter, drier gets drier”
  3. Widening of the Tropics, poleward shift of jet and storm tracks
    - particularly a summer phenomenon
- Multi-model means
  - robustness of model estimates increases with taking average of many models
- Degree of model agreement
  - good agreement for winter increase in precipitation
- Bias correction by statistical downscaling

# Cautionary Note

- Models are not perfect
  - Coarse resolution
  - No explicit simulation of precipitation processes
  - Individual and systematic errors
- Statistical downscaling
  - Assumption of stationarity: Same corrections are applied to current and future climate
- Uncertain assumptions about future emission scenarios

# Impact on Water Supply

- Retention of winter precipitation in the form of snow and gradual release by summer melt is an integral part of Utah's water supply
- Availability of water is thus controlled by
  - 1. precipitation**
  - 2. temperature** (snow fraction, snow melt, evaporation)
  - 3. mean, variability, and seasonal cycle**
- Temperature and precipitation increase have opposing effects, making the overall outcome uncertain
- More work is required to address this issue

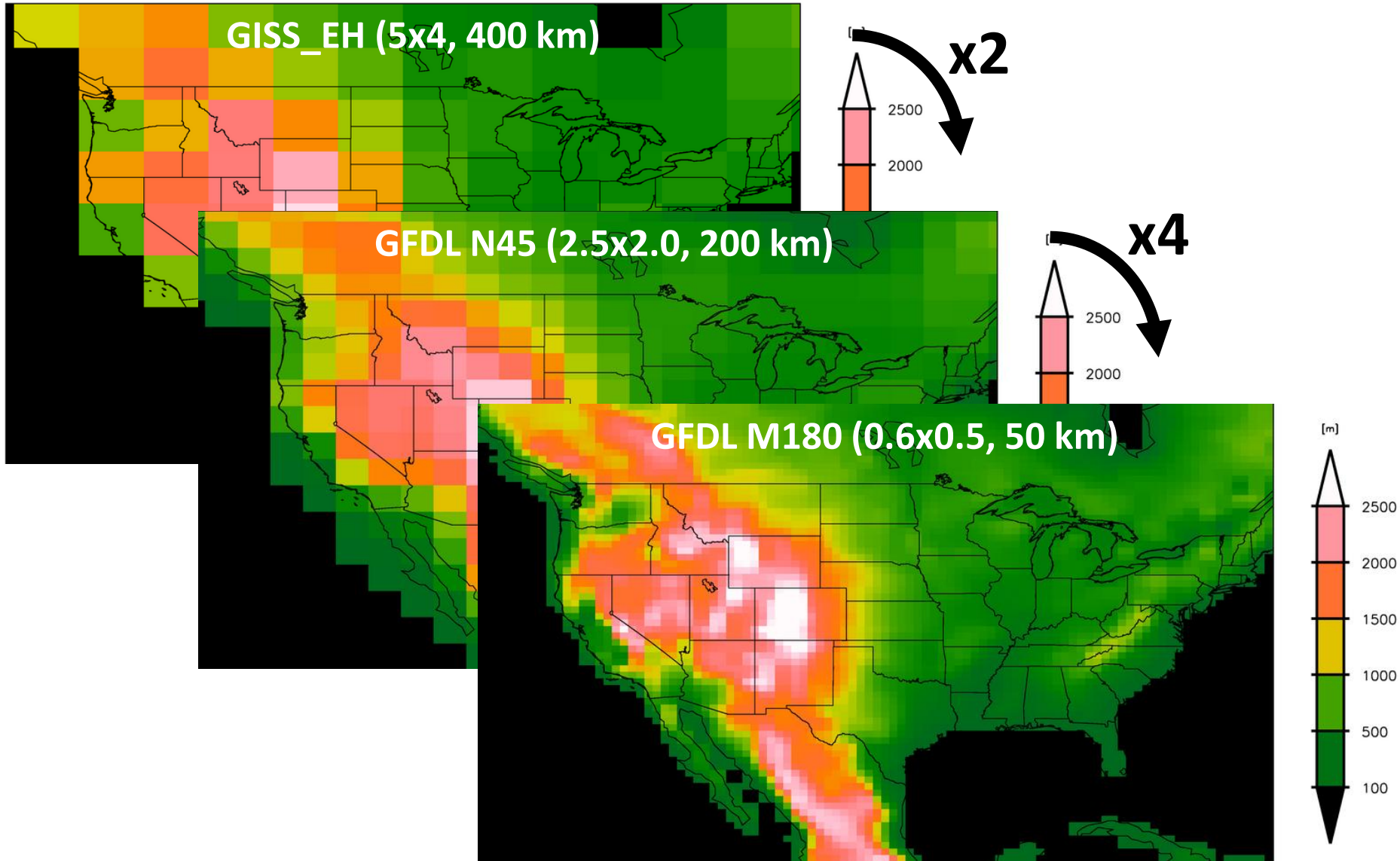
Thank You





# Spatial Resolution

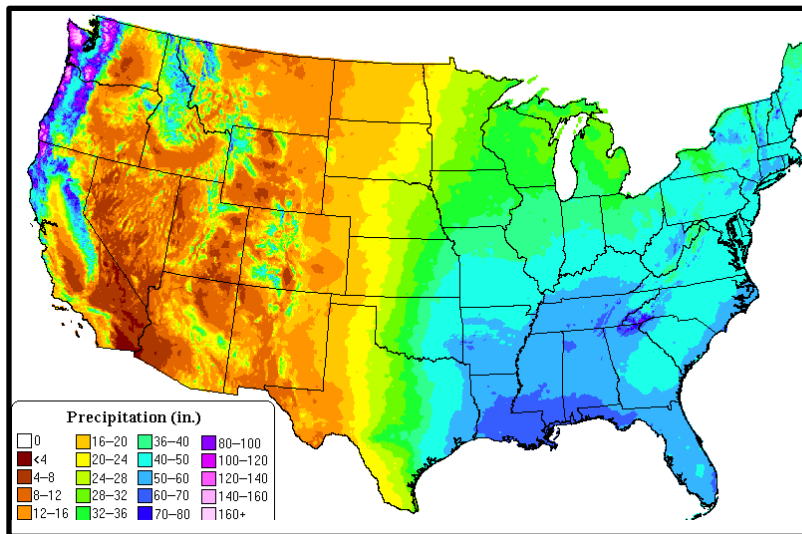
model orography [m]



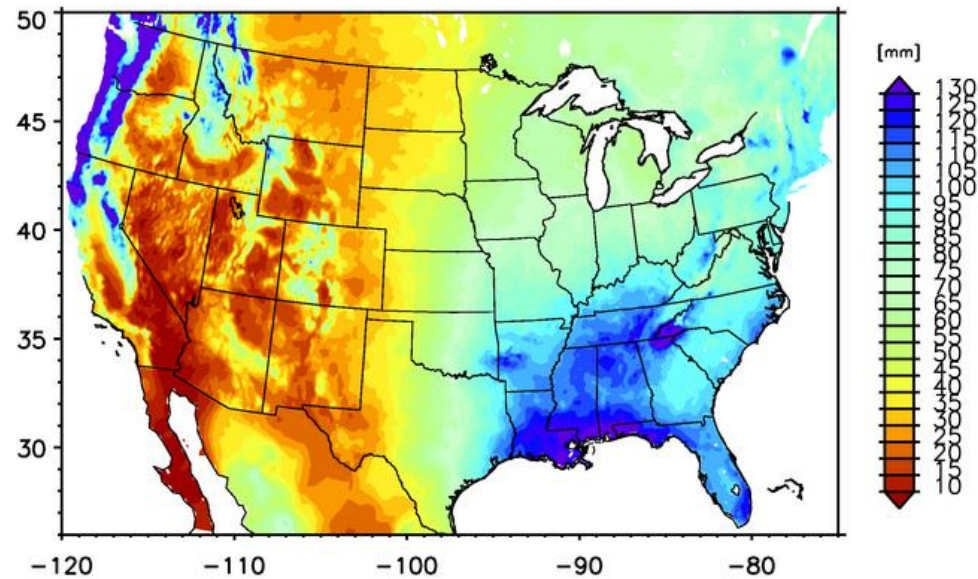
# Example: US Precipitation

annual climatology (mm/month)

PRISM ("observations"), 1971-2000



Downscaled model data 1980-1999

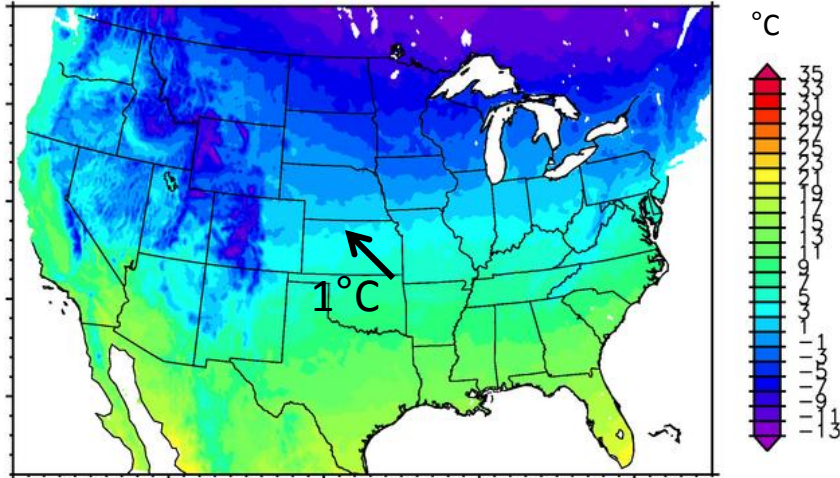


# Temperature Change

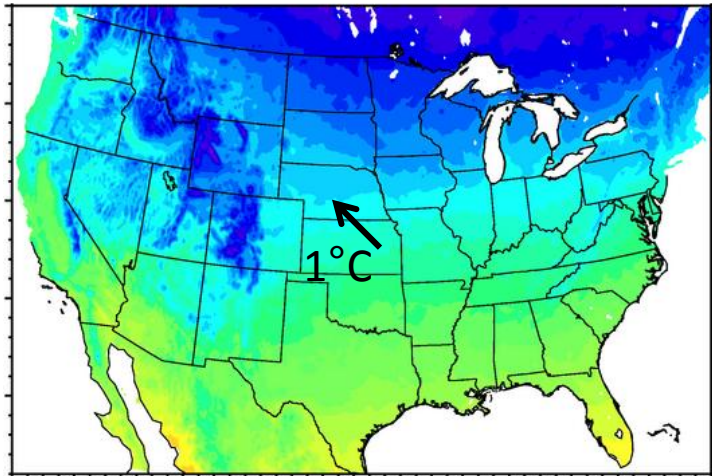
A1B, 1990 vs. 2050

Nov-Apr

1980-1999



2040-2059

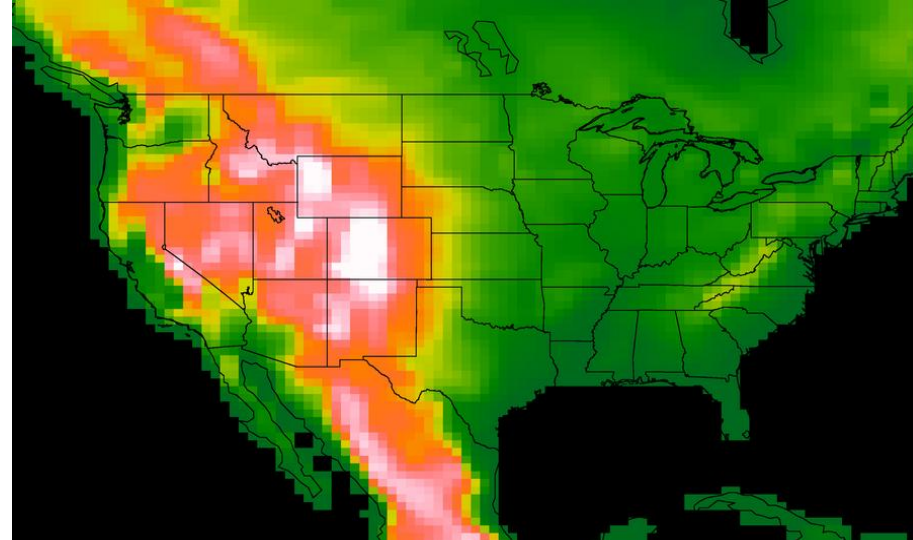




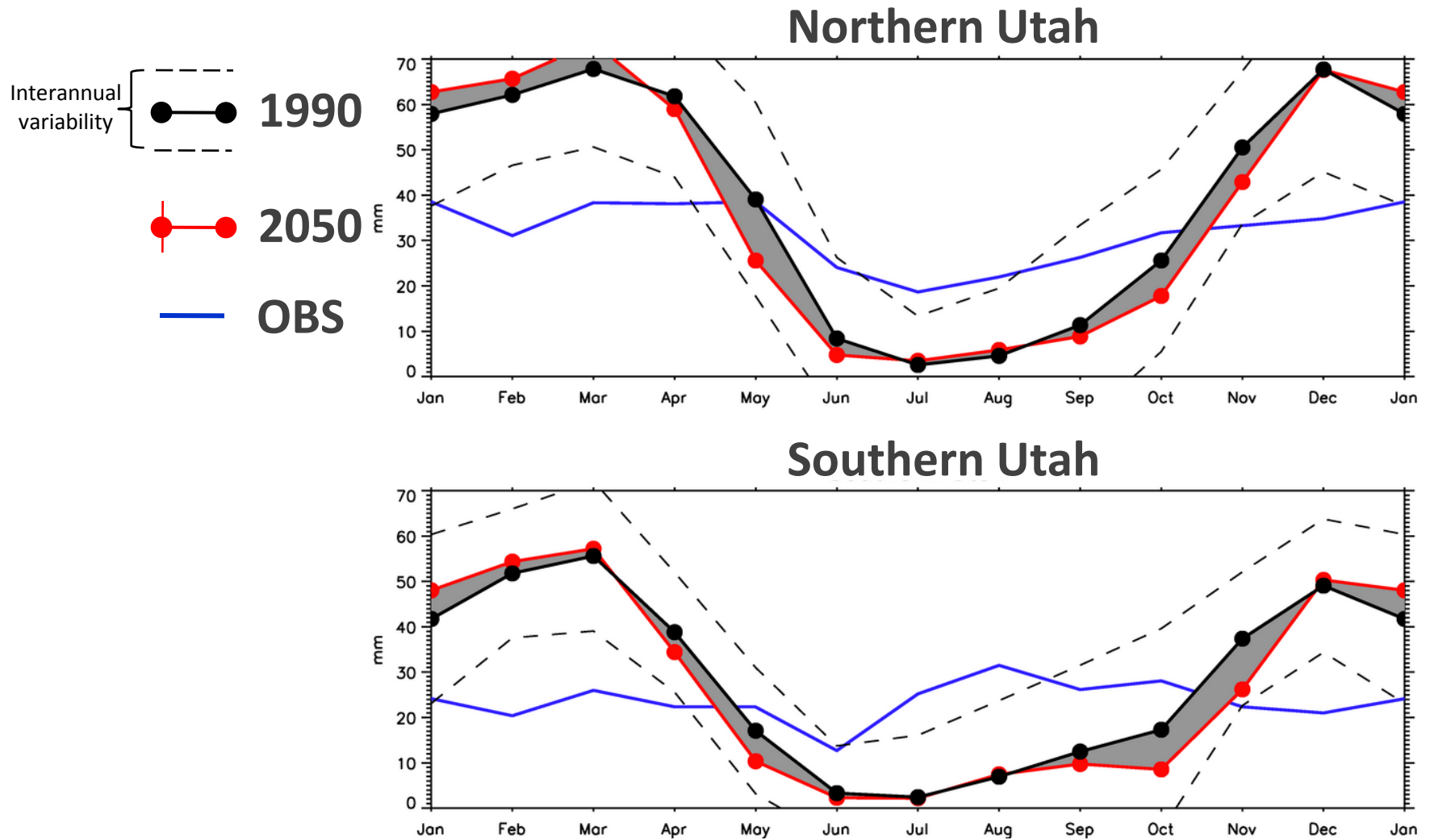
# Dynamical (Downscaling)

## Preliminary results

- North American Regional Climate Change Assessment Program (NARCCAP)
- [www.narccap.ucar.edu](http://www.narccap.ucar.edu)
- Not yet completed
- Preliminary results: GFDL AM2.1 (M180)
  - 0.6x0.5, 50 km
  - 1 model and 1 member only
  - SRES A2
  - 28 year averages: 2039-2066 vs. 1969-1996



# Precipitation Change: A2



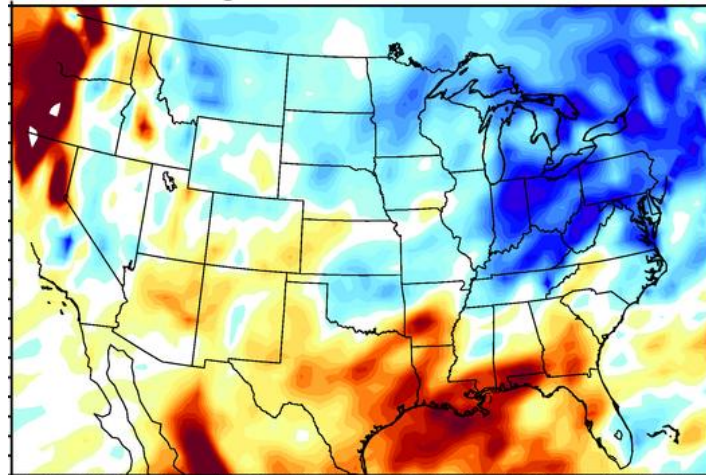
# Precip.: High vs. Low Resolution

GFDL, A2, 2039-2066 minus 1969-1996, 1 member

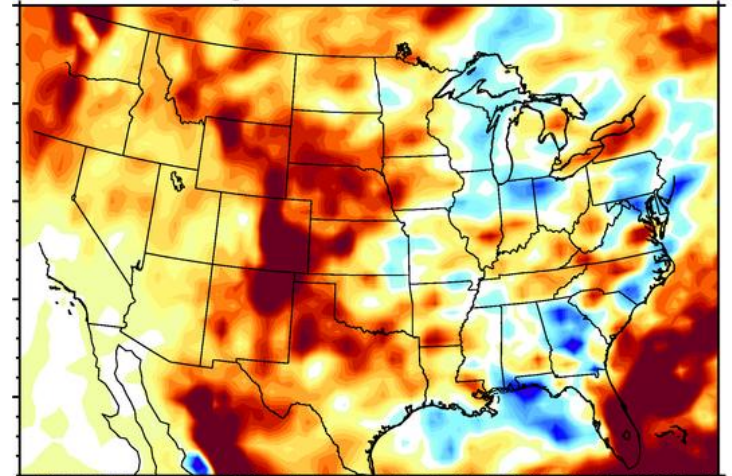
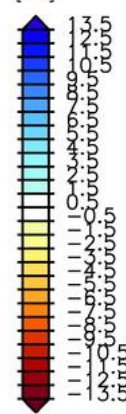
Nov-Apr

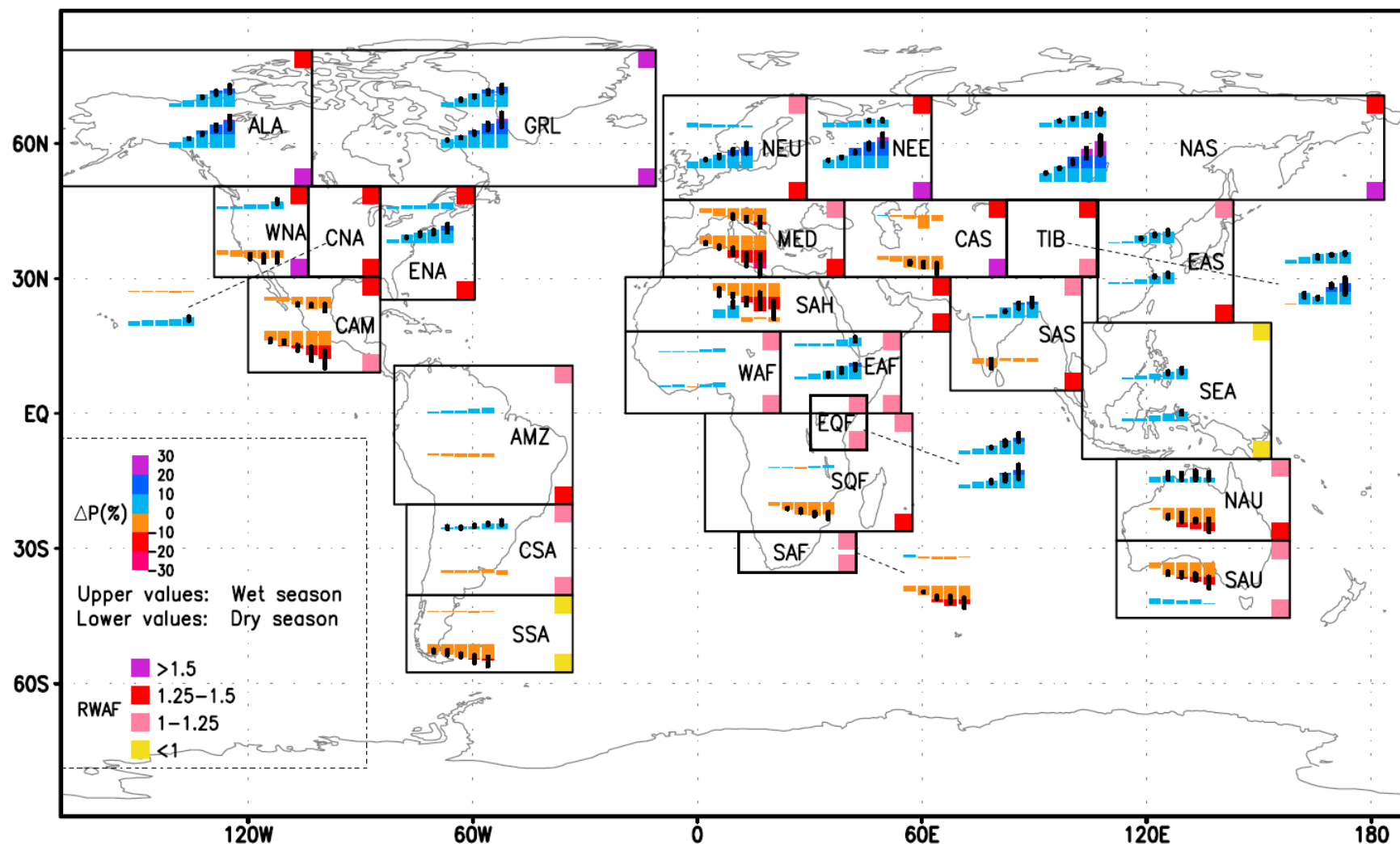
May-Oct

High-res



mm/month





For A1B scenario during 21<sup>st</sup> century, average of ca. 20 models.

globally:  $dT=0.7$   $1.2$   $1.8$   $2.3$   $2.9$  °C,  $dP = 1$   $1.7$   $2.6$   $3.7$   $4.6$  % (2000-2019, 2020-2039, 2040-2059, ... 2080-2099)

From: Giorgi and Bi (2005): Updated regional precipitation and temperature changes for the 21<sup>st</sup> century from ensembles of recent AOGCM simulations, GRL.

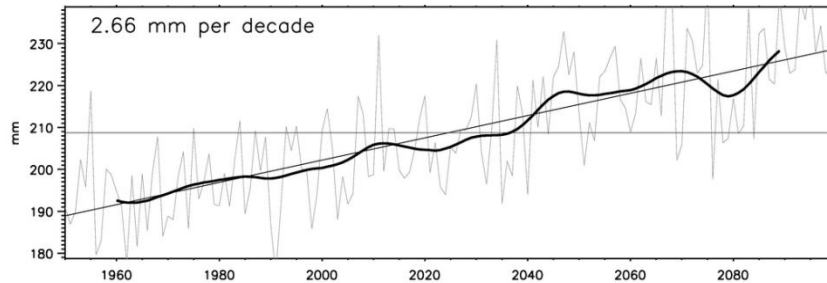


# Precipitation

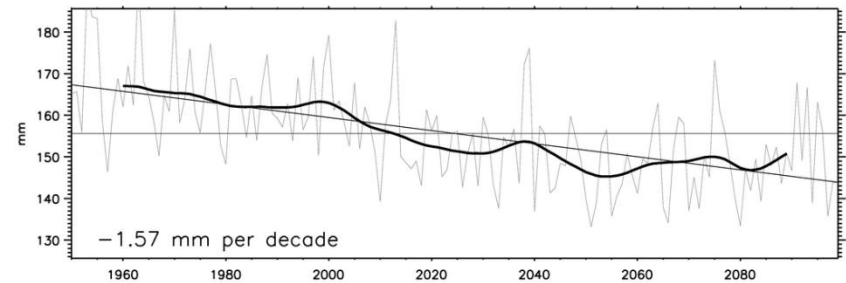
## Northern Utah

A1B

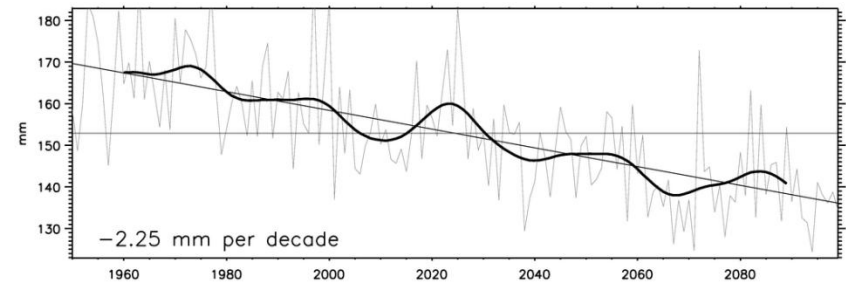
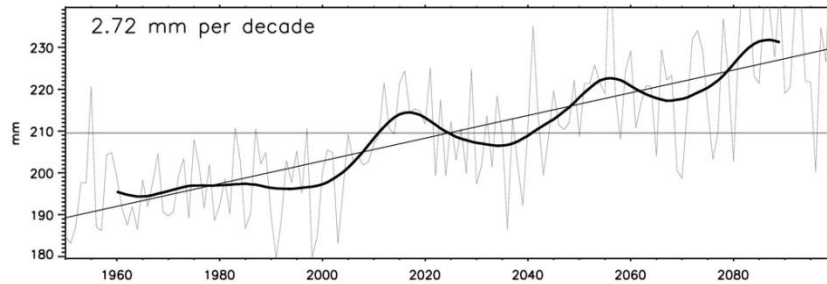
Nov-Apr



May-Oct



A2

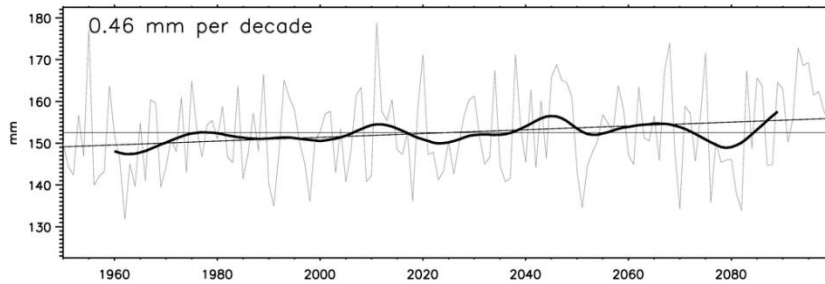


# Precipitation

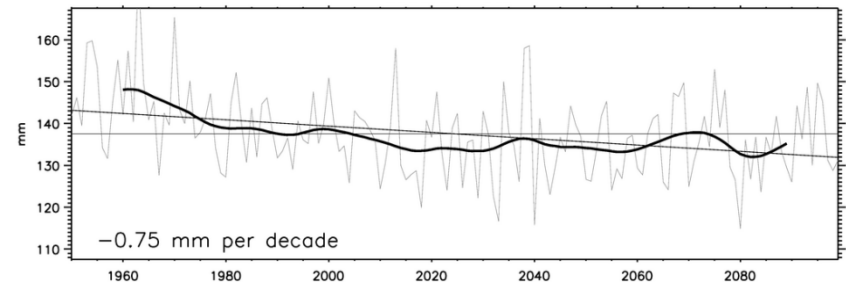
## Southern Utah

A1B

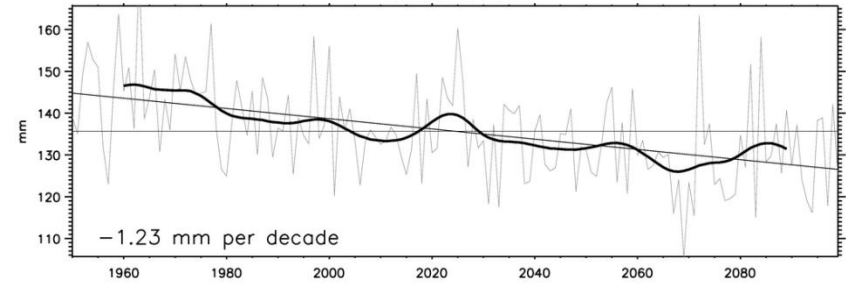
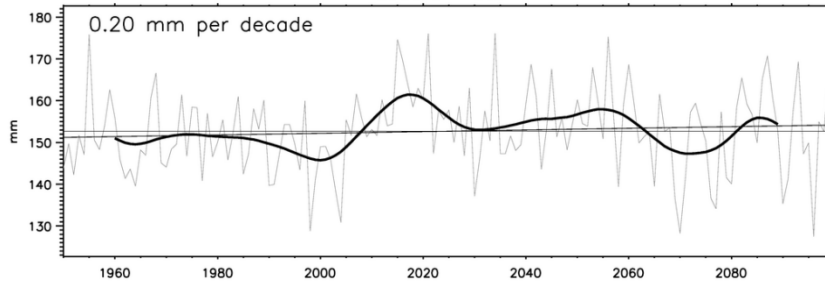
Nov-Apr



May-Oct



A2

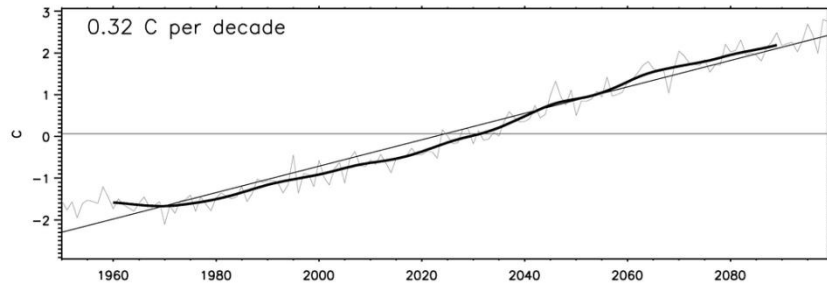


# Temperature

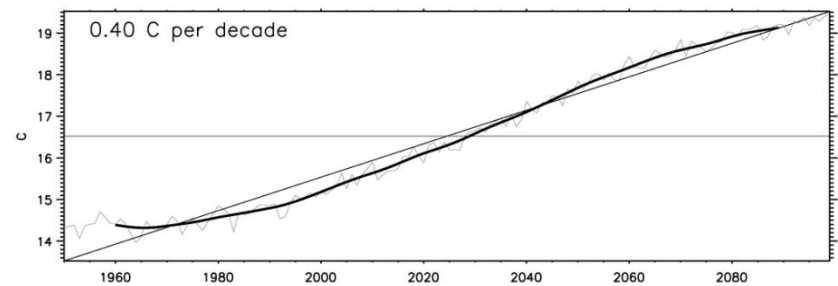
## Northern Utah

Nov-Apr

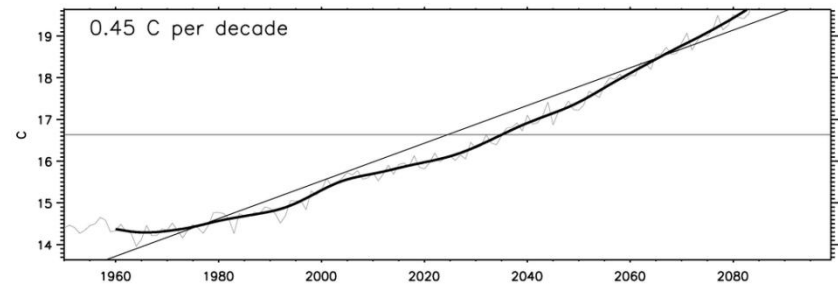
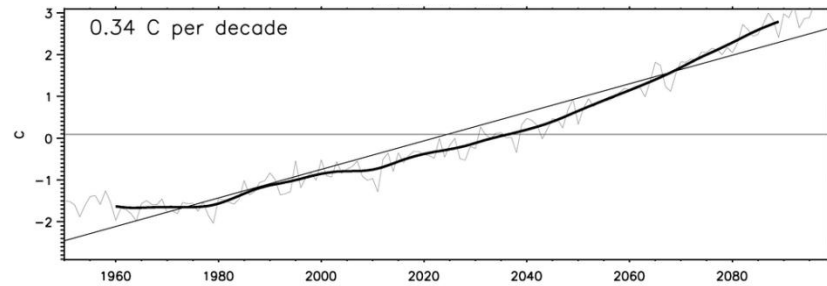
A1B



May-Oct



A2



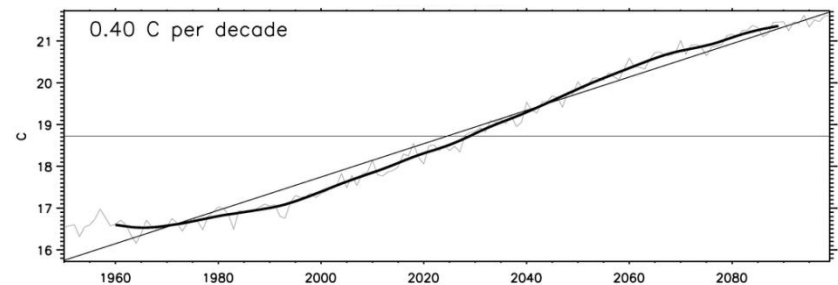
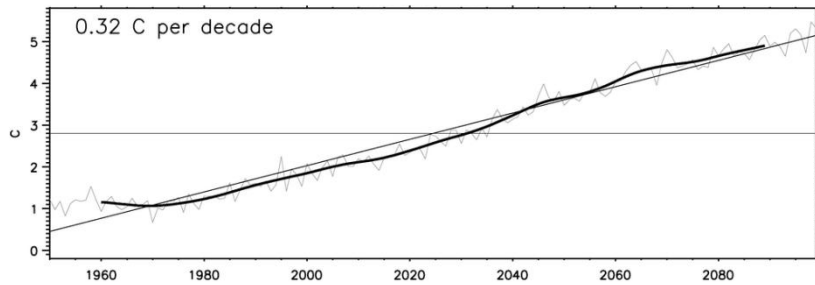
# Temperature

## Southern Utah

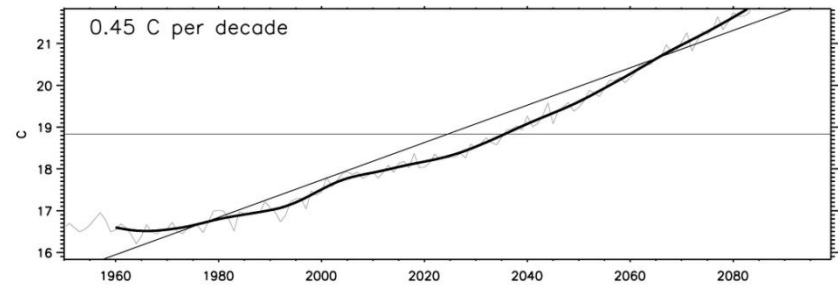
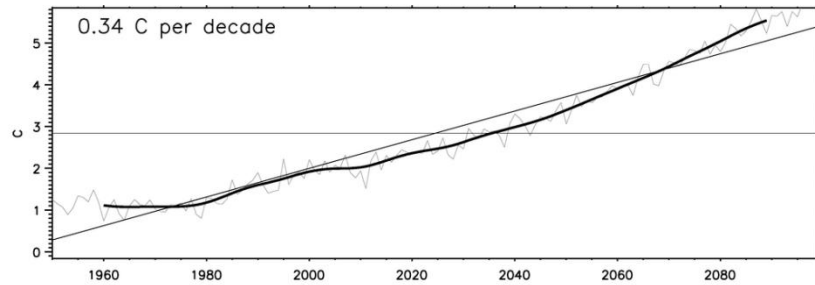
Nov-Apr

May-Oct

A1B



A2



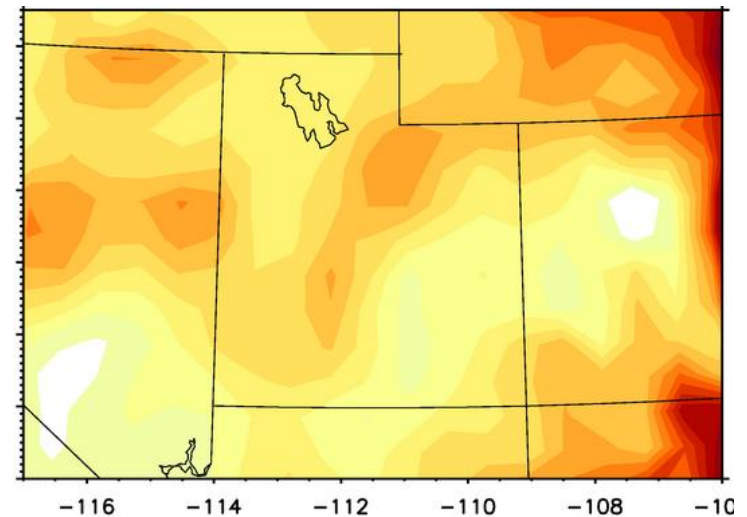
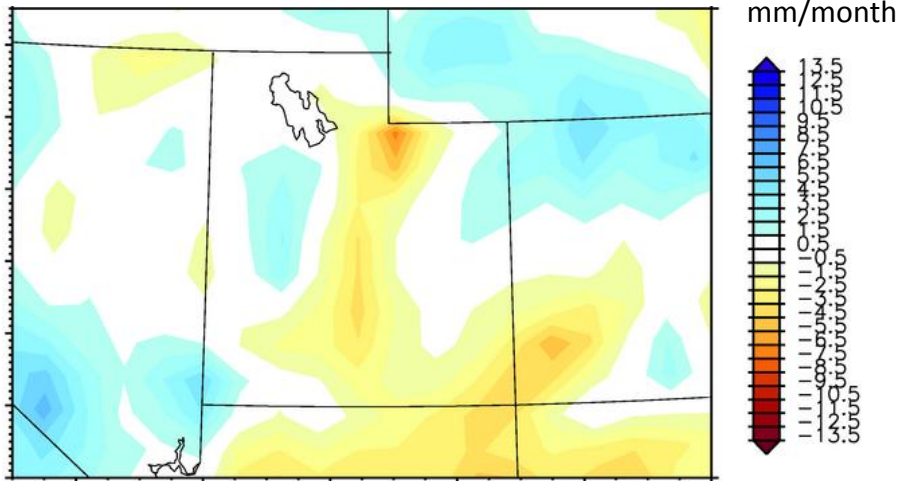
# Precipitation GFDL AM2.1 (M180)

A2, 2039-2066 minus 1969-1996

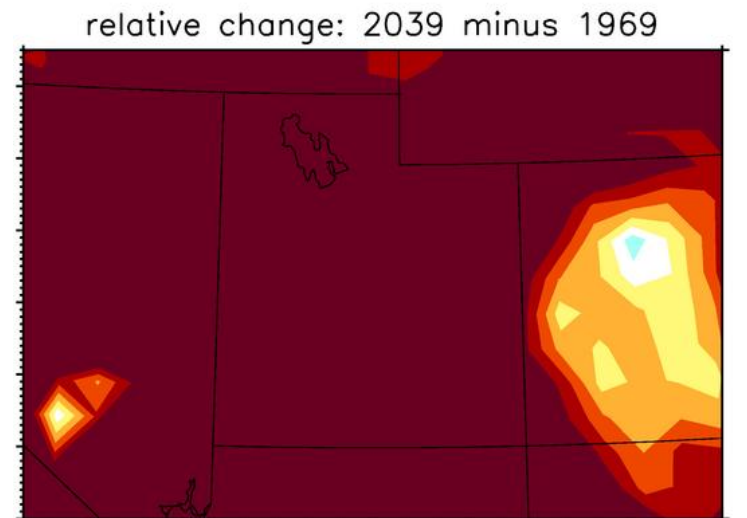
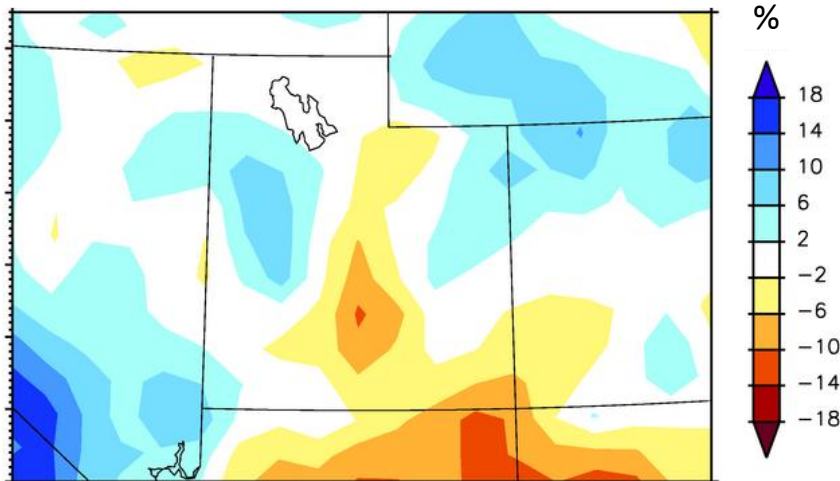
Nov-Apr

May-Oct

Absolute



Relative



relative change: 2039 minus 1969